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38 A Proposal for a Rapid Transition to Market Allocation of Spectrum

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A Proposal for a Rapid Transition to Market Allocation of Spectrum

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Abstract

Presently only about 7 percent of the most valuable spectrum is available for market allocation. To facilitate the rapid transition from administrative allocation of spectrum to market allocation, this paper proposes that the FCC (1) reallocate restricted spectrum to flexible use; (2) conduct large-scale, two-sided auctions of spectrum voluntarily offered by incumbents together with any unassigned spectrum held by the FCC, and (3) provide incumbents with incentives to participate in such "band restructuring" auctions by immediately granting participants flexibility and allowing them to keep the proceeds from the sale of their spectrum. Incumbents choosing not to participate would be allowed to continue current operations and would receive full flexibility in 5 years. Auction participants would stand to benefit from the increased value of their spectrum due to immediate flexibility and efficient restructuring. An incumbent would not be required to sell to get flexibility as long as it participates in the auction. Even if a license is not sold, the simple act of including the spectrum in the auction would make the opportunity cost of holding a license more apparent. By ensuring that most interdependent spectrum is up for sale at the same time, this proposal would facilitate a rapid and efficient restructuring of spectrum rights and use. We propose an initial implementation that in as little as 2 years could restructure 438 MHz of this most valuable spectrum, increasing the total available for market allocation from 7 percent to 23 percent.

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Executive Summary

The current administrative allocation of spectrum has led to shortages and waste. Markets can move spectrum to its highest value use both now and in the future, even as technology and consumer preferences change. But moving to an efficient market allocation will require a large scale restructuring of presently assigned and unassigned spectrum into flexible packages of rights that can be readily traded in the marketplace.

This paper proposes that the FCC facilitate the rapid transition from administrative allocation of spectrum to market allocation by (1) reallocating a large amount of presently restricted spectrum to flexible use; (2) conducting large-scale, two-sided "band restructuring" auctions of spectrum voluntarily offered by incumbents together with any unassigned spectrum held by the FCC; and (3) providing incumbents with incentives to participate in such auctions, by immediately granting participants flexibility and allowing them to keep the auction proceeds from the sale of their spectrum. Incumbents who choose not to participate in the auction would be allowed to continue to operate under the terms of their current licenses and would receive full flexibility after 5 years.

Under this approach, incumbents would have strong incentives to participate voluntarily and to allow their spectrum to move quickly to higher valued uses. By doing so they would share in the gains from immediate flexibility as well as from the rapid and efficient combining and restructuring of their spectrum together with highly complementary spectrum assigned to other incumbents and held by the FCC. Incumbents would not have to sell their spectrum to gain flexibility as long as they participate in the auction. Even if a license is not sold, a useful purpose will have been served by inducing the incumbent to participate thereby making the opportunity cost of holding a license more apparent. By ensuring that most interdependent spectrum is up for sale at the same time, this proposal would facilitate a rapid and efficient restructuring of spectrum rights and use.

Some have suggested that simply granting incumbents flexibility in the use of their spectrum is all the Commission needs to do to ensure the emergence of an efficient market allocation. However, our analysis suggests that this simple approach will not suffice. There are a number of reasons for this conclusion:

First, just granting incumbents flexibility would not make spectrum held by the FCC and NTIA available for flexible use. In many bands, spectrum is assigned on an as needed basis and unassigned spectrum is retained by the FCC or NTIA. This unassigned spectrum needs to be licensed so that it can be combined efficiently with encumbered spectrum.

Second, it would not reconfigure existing spectrum rights into tradable flexible rights. In many bands, the spectrum assigned to licensees is defined as a detailed set of technical specifications on transmitters (*e.g.*, frequency, bandwidth, power, modulation type, location, etc.) that cannot be changed without government approval. To provide licensees with technical and service flexibility, these "input" specifications need to be redefined in terms of "outputs", such as power limits at the boundaries between spectrum blocks and geographic areas. Subject to these output limits, each licensee would then be free to offer a variety of services and deploy

transmitters and system architectures of various designs within its licensed spectrum block and area. While converting input limits to output limits is necessary to give incumbents flexibility, it may not be practical for licenses covering only a small amount of spectrum, *e.g.*, point-to-point microwave licenses. Such small licenses may need to be combined together or dissolved into an overlay license to form packages large enough to afford any practical opportunity for flexibility.

Third, it would not solve coordination problems that can arise when all relevant spectrum is not available simultaneously for purchase. A single large-scale two-sided auction for all exclusively allocated spectrum would help bidders to combine encumbered and unencumbered spectrum into efficient packages. It would also allow bidders to efficiently choose among substitutable spectrum licenses. It is not obvious whether a private party could successfully run such a large-scale band-restructuring auction or what happens if multiple firms wish to run an auction for the same spectrum.

Fourth, it would not solve critical incentive problems that can prevent welfare-enhancing trades. Conflicting incentives within firms, sometimes referred to as the principal-agent problem may prevent efficient participation. The interests of spectrum managers within a firm are not necessarily aligned with the interests of the firm as a whole. Also incumbents may have incentives to strategically hold out for a bigger share of the gains from putting spectrum to higher value use. The FCC may be in the best position to conduct a large-scale two-sided band-restructuring auction and solve the incentive problems associated with ensuring participation and mitigating holdouts.

We conclude that the FCC can play a unique and profound transitional role in overcoming these shortcomings by organizing a series of large-scale spectrum auctions in which any unassigned spectrum can be combined efficiently with spectrum *voluntarily* supplied by incumbent licensees. Such large-scale band-restructuring auctions would allow spectrum users to quickly unscramble the inefficient spectrum allocations that have resulted from eighty years of central planning, and thereby allow spectrum to be employed in the manner that best serves the public. We propose an initial implementation that in as little as 2 years could restructure 438 MHz of spectrum in the 300 to 3000 MHz range and significantly reduce current spectrum shortages for high demand uses. Added to presently flexible spectrum, the proposal would triple the proportion of spectrum in this range available for market allocation from approximately 7 percent to 23 percent.

A Proposal for a Rapid Transition to Market Allocation of Spectrum

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1 Introduction

A consensus is forming that the current process of allocating radio spectrum by administrative decision-making is in serious need of reform. In a recent press conference the Chairman of the Federal Communications Commission, Michael Powell, said, "Put simply, our Nation's approach to spectrum allocation is seriously fractured..."[1] Billions of dollars of cumulative loss to the U.S. economy have been attributed to inefficient spectrum allocations under the current system.[2] The solution, according to most economists, is to replace the current administrative allocation with a spectrum market.[3] As Chairman Powell put it, "It is important that the Commission move from its traditional spectrum management paradigm of "command and control" to a paradigm of market-oriented allocation policy to provide more flexible allocations that allow multiple uses so that spectrum can be put to its highest and best use."[4] But specific proposals for a rapid transition to a broad-based spectrum market have been lacking. While the Federal Communications Commission (FCC) has made incremental progress in making flexible spectrum allocations, the process is far too slow. Currently, only about seven percent of the most valuable spectrum (in 300 MHz - 3,000 MHz range) is available for market allocation, *i.e.*, is flexibly allocated and exclusively and exhaustively licensed.[5] The rest is

[1] Powell (2001, p.5)

[2] Jackson, Kelley and Rohlfs (1991) estimated the lost consumer welfare from the 10 year delay in cellular service at about $86 billion, and Hausman (1997, p.23) estimated it at about $34 billion per year.

[3] *See* for example, Coase (1959), Hazlett (2001), Katz (1996), Kwerel and Williams (1992), Rosston and Steinberg (1997), Shelanski and Huber (1998), Webbink (1980, 1987), White (2001), 37 Concerned Economists (2001).

[4] Powell (2001, p.5)

[5] The 300 MHz – 3,000 MHz range has propagation characteristics that make it ideally suited for mobile applications. The primary spectrum currently available for flexible use, and thus subject to market allocation, is 50 MHz allocated to cellular, 90 MHz allocated to PCS and 15 MHz allocated to SMR. An additional 30 MHz of PCS spectrum should be available for flexible use soon pending the resolution of the Nextwave settlement. It should also be noted that use of some of the PCS spectrum is limited to "designated entities" so it is not fully available to the market.

restricted to specific uses, technologies and/or users, is licensed on a shared basis, or is only partially licensed under an administrative system that rations spectrum on a first-come or as needed basis with unassigned spectrum held by the FCC or the National Telecommunications and Information Administration (NTIA) for future assignment.

This paper proposes a means to speed the transition from the current restricted spectrum allocation to an efficient market allocation. A key aspect of the proposal is the use of a two-sided auction in which the FCC would offer unassigned spectrum in a band (sometimes referred to as "overlay licenses" or "white space") simultaneously with encumbered spectrum offered by existing licensees. The simultaneous auction of encumbered and unencumbered spectrum in a band would allow bidders to acquire highly complementary spectrum assets quickly in a single event rather than through the current sequential process consisting of an FCC auction followed by post-auction negotiations with incumbents. Ideally, all technically fungible spectrum, *e.g.*, everything from 300 to 3000 MHz, would be included in a single auction. This ideal scenario would also include spectrum now reserved for government use[6] and bands that might be used for the relocation of incumbents. However, practical considerations that we will discuss below constrain us to propose something more limited as an initial implementation. The nature of current use also suggests that certain bands will be more suitable for this approach than others. Taking these factors into account we propose an initial implementation that we believe is practical yet large enough to provide significant benefits. If implemented, it could make available in as little as two to five years 438 MHz of very desirable spectrum for such potentially high value uses as next generation mobile services.[7] Assuming satisfactory results from the initial application of this approach, we propose that it be extended more broadly across a wide range of spectrum to bring about a permanent, systemic solution to the spectrum allocation problem.

There are some other important aspects of our proposal that we will mention here and discuss in more detail below. For our proposal to work, incumbents must participate in the

[6] The National Telecommunications and Information Administration (NTIA) of the U.S. Department of Commerce has jurisdiction over government spectrum, most of which is used by the Department of Defense.

[7] Analog voice cellular is considered first generation and digital cellular and PCS second generation. Third generation (3G) mobile services will include voice and higher speed data. A more detailed definition is available at FCC website http://www.fcc.gov/3G/.

auction. To encourage such participation, we propose that incumbents be allowed to keep all proceeds from the sale of encumbered spectrum. To further encourage participation, we propose that the spectrum encumbered by an incumbent who does not participate in the auction be frozen in its current allocation for five years. Participation would thus become a *quid pro quo* for incumbents' receiving flexibility of use, and what could be a substantial windfall from transfer of their spectrum to a higher valued use. We propose to further protect incumbents by allowing them to bid on their own licenses in the auction. This would ensure an incumbent's spectrum is not sold for less than its value to the incumbent. Since the cost to participate in the auction should be small relative to potential gains from flexibility of use, a high level of participation is likely.

In the Section 2 we describe the elements of an "ideal" regime for market allocation of spectrum, compare it with the present administrative system, and suggest rule changes that will be necessary to transition to a market system. In Section 3 we discuss critical elements of any transition mechanism. In Section 4 we describe our specific proposal for an efficient transition mechanism and analyze it with respect to the efficiency criteria developed in Section 3. In Section 5 we examine practical issues that will arise in applying our proposal to different bands in the 300 to 3000 MHz range, and conclude with a table proposing specific bands for initial implementation. In Section 6 we discuss legal authority and the incentives to implement our proposal. Our final conclusions are presented in Section 7.

2 Elements of a Market Regime for Spectrum

Before explaining our proposal in detail, we review the basic components of an ideal regulatory regime that ensures an efficient market allocation of spectrum. Comparing this ideal with the current situation suggests the kind of rule changes that will be needed to implement an efficient market allocation.[8]

2.1 Flexibility of Use

The Ideal: In a market allocation of spectrum, markets, not central authorities, determine spectrum uses and users. An ideal market allocation should impose no restrictions on spectrum

[8] For additional discussion on efficient definition of flexible spectrum rights see the appendix.

uses and users beyond those necessary to limit interference, to prevent anti-competitive concentration, and to comply with international agreements. Spectrum should not be set aside for federal users or for specific non-federal users such as public safety providers, and public users should be allowed both to sell spectrum and buy spectrum from the private sector. For example, police and fire departments should be able to sell some of their spectrum and use the proceeds to buy new spectrum-conserving radios that could provide greater capacity and interoperability.

Current Situation: Most spectrum is currently designated for specific uses or users, *e.g.*, federal government agencies, state and local public safety agencies, broadcasting, navigation, radar, satellites, etc. This division of spectrum by use or user category is referred to as "block allocations" and the categories are generally referred to as "services". The degree of flexibility permitted in different services varies widely. For example the Personal Communications Service (PCS) permits any fixed or mobile use and technology, whereas the Television Broadcasting service is quite narrowly defined both in the nature of the use permitted and the technology. Presently only about seven percent of the 300 MHz to 3000 MHz range is allocated for flexible use.[9] Instituting an efficient market allocation across a wide range of spectrum will thus require departures from the current system of block allocations.

2.2 Exhaustive assignment of spectrum rights

The Ideal: If a market is to ensure efficient allocation of all spectrum, all spectrum rights should be assigned exhaustively in all dimensions (frequency, geography, time and use). Thus, as part of the general transition to a market allocation system, the FCC and NTIA should assign all presently unassigned spectrum in bands where the assignment is presently incomplete. This will allow the market to combine presently assigned and unassigned spectrum rights into efficient packages.

Current System: Under the current block allocation approach, spectrum in many bands is assigned on an as-needed basis, and licensees are given only as much as is deemed to be needed for the specific system or service contemplated. The FCC and NTIA hold unassigned spectrum

[9] The primary spectrum currently available for flexible use, and thus subject to market allocation, is 50 MHz allocated to cellular, 90 MHz allocated to PCS and 15 MHz allocated to SMR. An additional 30 MHz of PCS spectrum should be available for flexible use soon pending the resolution of the Nextwave settlement.

in reserve for future assignment. Transitioning to the ideal system will require exhaustive licensing of unassigned spectrum. The FCC's approach in the PCS bands provides a useful model.[10] The FCC exhaustively assigned spectrum blocks over large geographic areas with interference protection for incumbent uses: it licensed the "Swiss cheese" and protected the "holes." Overlay licenses, such as defined in the PCS bands, allow for immediate use of clear (unencumbered) spectrum and integration of occupied (encumbered) spectrum as it is cleared.

2.3 Exclusive licenses

The Ideal: With licenses for the exclusive use of the spectrum, private parties have the ability and incentive to make efficient choices about spectrum use. Exclusivity internalizes both the costs and benefits of decisions about spectrum use and minimizes coordination and other kinds of transaction costs. Spectrum rights should thus be assigned exclusively in frequency, space and time.[11] Assigning spectrum exclusively does not preclude the use of intensive engineering techniques that permit economically efficient sharing of spectrum by multiple users, as for example, various space, time or frequency multiplexing techniques. Licensees with exclusive rights would have the correct incentives to develop and implement such techniques to maximize the value of their spectrum.

The Current System: In some bands, *e.g.*, the 450 MHz private land mobile radio service (PLMRS) bands, spectrum is licensed on a shared basis.[12] Thus, multiple licensees in an area are authorized to use the same frequency channel on a time-shared basis. Sharing etiquettes are imposed to facilitate coordination and prevent hoarding. For example, licensees may be required to listen before they transmit to avoid interference. In shared bands, just providing technical and service flexibility would not create the correct incentives for economically efficient use of the spectrum, because licensees can not capture the benefits from deploying spectrum-conserving equipment. When a licensee reduces its usage in a shared use regime, it makes more spectrum

[10] For a detailed description of the licensing and band clearing approach used in the PCS bands, see Crampton, Kwerel and Williams (1998), pp. 660-669.

[11] Because the Communications Act prohibits the Federal Communications Commission from transferring title to radio frequency spectrum to third parties, see 47 U.S.C.A. § 301, licensees cannot "own" spectrum. We do not believe that licensees must have fee simple ownership of spectrum for markets to efficiently assign and allocate spectrum. It is sufficient for the Commission to provide for exhaustive, flexible, exclusive, transferable spectrum-usage rights and strong license-renewal expectancies.

[12] FCC (1995b), para. 2.

available for use by other licensees. But absent compensation for the benefits that accrue to others, licensees do not have sufficient incentives to conserve on spectrum use, congestion develops and economic output is less than optimal. This problem is sometimes referred to as a "tragedy of the commons," and can occur in non-exclusively licensed spectrum as well as unlicensed spectrum (see discussion of low power devices, below).[13] To provide the correct incentives in a flexible market–based regime, shared use licenses should be replaced with exclusive licenses. However, converting shared spectrum to exclusively licensed spectrum presents difficult transition problems that are discussed in more detail in Section 5.

2.4 Proper definition of interference rights

The Ideal: To provide licensees maximum technical and service flexibility, spectrum emissions rights between licensees should be defined in terms of power limits at the boundaries between spectrum blocks and geographic areas together with maximum in-band power limits. Subject to these output limits, each licensee should be free to deploy transmitters within its licensed spectrum block and area without coordination with licensees in adjoining blocks and areas. Conversely, each licensee must design its own receiving system to tolerate permissible levels of interfering power from adjoining licensees. Under this definition of interference rights, receiver deployment near license boundaries may be significantly constrained because of potential interference from neighboring licensees. However, licensees can use a variety of interference mitigation techniques to deploy receivers in such areas. They may also modify the default limits by mutual consent and agree to coordinate operations to facilitate a more efficient deployment in boundary areas. Negotiated changes in the initially set boundary limits should be reported to the FCC for purposes of registration to assist subsequent market transactions.

The Current System: The general approach of using boundary limits has been used successfully in the PCS and other flexibly allocated bands. However, in many bands, the existing interference rights are often defined as a set of technical specifications such as frequency, power, modulation type, location, direction, etc., that cannot be changed without further approval. Where feasible, the FCC and NTIA should redefine these current licensed rights into explicit, physical flexible rights based on boundary limits, with flexibility to deploy

[13] Hardin (1968).

transmitters within those boundaries. This is most feasible for large exclusive licenses, such as UHF TV or satellite licenses that exclusively encumber a large block of spectrum over a large area. However, licenses covering only a small amount of spectrum, *e.g.*, point-to-point licenses, may not afford significant flexibility even if converted to boundary limits. In such bands, it may be necessary to merge many existing licenses into one or dissolve them into a larger, flexible overlay license. Also, any conversion of current licenses to flexible licenses with boundary limits will require additional, specific technical rules to protect current uses. Boundary limits provide an appropriate interference regime for new uses on a forward going basis, but do not address the need to protect existing systems.

2.5 Special provisions for low-power devices

Some uses of spectrum, such as cordless telephones, 802.11 wireless networks, and garage door openers, occupy so little spectrum that it may not be efficient to charge for their use (since the opportunity cost of adding devices is virtually zero). Many of the unlicensed devices currently accommodated under Part 15 of the FCC's rules may fall into this category. The Commission has provided for unlicensed uses by allowing such devices on a non-interfering basis in licensed spectrum and by allocating dedicated spectrum for their use.

Some special administrative provisions for low power devices may be efficient in a market system. However, in making decisions about the amount of spectrum allocated to unlicensed use, the government should face the opportunity cost of limiting or foreclosing other use. Just as the government decides how much land to purchase for public parks, it would decide how much spectrum to set aside for unlicensed devices. A market system would also provide the opportunity for private spectrum licensees in flexible bands to compete with the government for the provision of spectrum for low-power devices, just as private facilities that charge admission compete with public parks. Licensees might find it profitable to do so by charging manufacturers of such devices to operate on their spectrum. This would allow private licensees to compete on the technical protocols and other quality factors instead of relying on government or industry committees.

It may also be efficient to continue to allow low-power, non-interfering uses of licensed bands (*i.e.,* limit the right of licensees to exclude such users). If such uses were truly non-

interfering, there would be no spectrum opportunity cost to accommodating them in this fashion. We assume this to be the case for low power uses now permitted, *e.g.*, radiation from computers or receivers, and will be the case for ultra-wide-band (UWB) devices. Moreover, in the UWB case, because the emission of the low power devices is spread across a wide range of spectrum, the transaction costs of private negotiations with many licensees may be prohibitive. Therefore, administrative provisioning for UWB devices may be necessary as a practical matter even if spectrum is generally allocated by a market.

To the extent there is contention among low-power devices, some form of rationing of usage among such users may be efficient. This might be accommodated by exclusively licensing the low power management rights to one or more "band managers."[14] The band manager would determine the etiquettes to be used and establish prices to ration demand.[15] The band manager would also be able to bargain with high power licensees for increased rights, *e.g.*, higher power limits, as a market alternative to administrative provisioning, at least for low-power uses that do not spread across a great many licensees.

3 Elements of an Efficient Transition to Spectrum Markets

As we have discussed, for a market to allocate spectrum efficiently, spectrum rights should be flexible and exclusive and all rights should be exhaustively assigned. This is not the situation that exists in most bands, where licensees are typically restricted to narrowly defined uses, are given only as much spectrum as is determined by the FCC to be "needed" for that use, and in some cases must time-share their spectrum. Transitioning from the current administrative system to a market allocation will thus require fundamental restructuring and redefinition of rights across a wide range of spectrum. The success of the transition will depend on how quickly and broadly this is accomplished.

[14] The FCC used the band manager approach in a portion of the 700 MHz spectrum reclaimed from TV channels 52-59, where it assigned "Guard Band Manager" licenses in certain bands adjacent to public safety spectrum. *See*, FCC (2000)

[15] Preferably, there would be more than one band manager to provide the benefits of competition. In any case, flexible licensees may be able to compete by providing similar provisions for low power devices, as discussed earlier in this section.

Current licensing restrictions do not permit efficient markets to arise naturally, so the FCC and NTIA should create a transition market mechanism. We will discuss some desirable properties of a transition market mechanism, with the caveat that no perfect mechanism exists.[16]

3.1 Speed

Speed is an essential attribute of a good transition mechanism because delaying the widespread market allocation of spectrum could cause tens of billions of dollars in lost benefits to consumers.[17] Speed should include the time to implement the mechanism, the speed with which the mechanism determines an efficient market allocation once implemented, and likely post-mechanism delays such as legal challenges. For example, the C block PCS auction took less than five months to complete, but most of the spectrum has still not been assigned more than five years after the auction closed because of litigation.[18] Post-mechanism delays can be more significant than delays of applying the mechanism itself. It may be impossible to implement any spectrum reform if it is perceived as unfair.

3.2 Low transaction costs

A good market mechanism for spectrum should have low transaction costs. This means low costs to participate and to run. Participation costs include not only direct out-of-pocket expenses but also the time of staff and management to buy or sell spectrum rights. Participation and market operation costs should be small relative to the value created by the transactions.[19]

3.3 Transparency

A good market mechanism should be transparent. A transparent process is clearly understood by participants and perceived as honest. If it is not, many parties will choose not to participate and some efficiency-enhancing trades will not occur. Transparency requires consistently enforcing rules and holding participants to their commitments. If, for example, an

[16] Myerson and Satterthwaite (1983) have shown that with many sellers and buyers, and voluntary participation, there is no efficient exchange mechanism where the required payments to the sellers do not exceed the amount paid by the buyers.

[17] *See* Jackson, Kelley and Rohlfs (1991), Hausman (1997), Kwerel and Williams (1992).

[18] FCC website: http://wireless.fcc.gov/auctions/summary.html#completed

[19] Since increased value is not easily measured, transactions costs are typically considered as a percentage of the total revenue from the items sold.

auction winner did not expect to pay the amount it bid in auction, but instead expected to be free to negotiate with the seller after the auction closed, the auction might consistently fail to award spectrum licenses to the parties that value them the most. Buyers would bid enormous sums for spectrum rights, knowing that they would not have to pay their bids, and the auction would be meaningless.

3.4 Liquidity

High liquidity is another desirable property of a market. In a highly liquid market a buyer or seller is always able to make a trade at a price close to a well-established market price. The spectrum market will be highly liquid if large portions of spectrum are technically and legally substitutable and if there are many sellers and buyers of spectrum, but no one so large that it can significantly affect prices.

Absent a liquid market for spectrum, incumbents do not have good information about the value of their spectrum, and potential buyers do not have good information of the cost of acquiring spectrum. A liquid market provides this information, and thus facilitates transfers of spectrum to its highest value uses. A liquid market for spectrum also reduces the "liquidity risk" of investing in spectrum-based services just as liquid financial markets reduce the risk of investing in financial assets. Buyers of liquid assets can sell those assets on short notice without incurring high search costs to find a buyer willing to pay the market price. A liquid spectrum market reduces the risk that a firm will be unable to sell spectrum that it does not need or that it will be unable to purchase spectrum that it does need.

3.5 Participation

All parties who can gain from trade should have the incentive to participate in the market mechanism. Two market failures that may prevent efficient trades are strategic holdouts and agents not pursuing the best interest of their principals. Strategic holdouts are a well-known phenomenon in large-scale real estate redevelopment projects when multiple incumbents must be cleared. Each incumbent who can individually block a project hopes to get a bigger share of the gain from development by being the last to settle. In some cases value-enhancing redevelopment is significantly delayed. In other cases, the project is changed to work around an incumbent who refuses to sell, and sometimes no redevelopment occurs even though it would be highly valuable.

Conflicting incentives within firms, sometimes referred to as the principal-agent problem, is the second market failure that may prevent efficient participation.[20] The interests of spectrum managers within a firm are not necessarily aligned with the interests of the firm as a whole. For example, employees responsible for managing a microwave communications system would oppose replacing the microwave system with a fiber optic system that would increase overall profits, if it means the loss of their jobs. Even changing the use of a firm's spectrum from fixed to mobile applications could damage the career of employees with expertise in only fixed applications. Since senior management typically delegates responsibility for spectrum policy issues to the managers responsible for spectrum-based communications systems, firms may make inefficient choices when faced with policy questions.

3.6 Simultaneity

Another property of an efficient market mechanism for spectrum is simultaneity: All highly complementary and substitutable spectrum should be available to the market at the same time. Ideally most spectrum over a wide frequency range, *e.g.*, 300 MHz to 3,000 MHz, would be available to the market during the transition because this entire spectrum block is potentially substitutable or might be part of useful aggregations. This includes spectrum under NTIA jurisdiction (now reserved for use by the federal government) as well as spectrum under FCC jurisdiction (for all other users). Any spectrum that would be useful for relocation of incumbents would also be included so that incumbents could buy relocation spectrum at the same time they sell current holdings.

The arguments for simultaneity are those that led the FCC to adopt its current simultaneous multiple round design for spectrum auctions.[21] Simultaneity provides buyers with information about the prices of relevant complements and substitutes, and allows them to act on that information – to combine complementary spectrum into the most efficient packages and to choose among substitutable spectrum. If complementary items are offered for sale sequentially, buyers seeking a package of items will not know how much to bid for those items first put up for sale without knowing the likely prices of the complementary items that will be up for sale later.

[20] Tirole (1988): 51-55.

[21] FCC (1994a, 1994c), McMillan (1994).

Lacking such information, they must guess and could end up not bidding for an item offered early in the sequence of sales because they overestimate the price of a complementary item to be sold later. Or they could end up winning an item at too high a price because they underestimated the price of a complementary item sold later.

Although post-auction transactions can reduce the inefficiency from a poorly designed initial auction, they cannot eliminate it. The experience of cellular providers combining licenses into larger geographic aggregations over many years suggests that such sequential transactions can be costly, and experiments provide evidence that sequential auctions will achieve a lower level of efficiency than simultaneous auctions when there are many highly complementary items.[22]

Buyers of substitutable items would face a similar difficulty with sequential sales. If buyers guess wrong, items may not be awarded to those with the highest valuations. To illustrate this point, suppose there are two licenses, A and B, that are perfect substitutes for three bidders, 1, 2 and 3. The three bidders have respective valuations of $100, $90 and $80 for either license. Suppose license A is put up for sale first and that bidders 1 and 2 incorrectly believe that license B will sell for less than $80, while bidder 3 believes that license B will sell for more than $80. Then as bidders 1 and 2 drop out of the first auction, waiting to bid on license B, bidder 3 would win license A for $80. Bidder 1 would subsequently win license B for $91. But in the efficient allocation, bidder 1 would win one license and bidder 2 the other license. This would be the outcome in a simultaneous multiple round (ascending bid) auction. Bidder 1 and 2 would each win a license and both licenses would sell for the same price, $81 (the lowest price that would force bidder 3 to drop out of the auction). In the above example, the inefficient outcome of the sequential auction could be corrected if bidder 3 resold license A to bidder 2. But such reselling typically entails additional transaction costs.

Simultaneity is also important for efficiency when there are multiple *sellers* of substitutable items. It ensures that the close substitutes sold are those that are valued least highly by the sellers. For example, suppose seller 1 values its license at $70 and seller 2 values an identical license at $50. If only one license is sold, it should be seller 2's license. With sequential sales,

[22] *See* Ledyard, Porter and Rangel (1997) for experimental evidence that simultaneous auctions are more efficient than sequential auctions when items are complementary.

incorrect guesses about future prices can result in a sale by a seller with a higher valuation than that of a seller of an unsold close substitute.

Simultaneity has additional efficiency benefits in a two-sided auction. Simultaneity provides useful price information for parties that wish to sell some items and purchase substitute items. An auction in which both spectrum held by the FCC and incumbent licensees is offered simultaneously, would provide incumbents simultaneous information about the prices of relocation spectrum that they may wish to buy and the spectrum they now occupy that they may wish to sell. If the incumbent's spectrum and possible relocation spectrum were sold sequentially, an incumbent might be reluctant to move because it could not be sure that the receipts from selling its spectrum would at least cover the cost of the relocation spectrum and other moving costs.

Simultaneously offering most substitutable spectrum may also reduce the holdout problem by reducing the market power of incumbents. When buyers are not dependent on any individual seller, potential sellers have little incentive to holdout. Sellers might as well participate in such an auction and sell if the price exceeds their reservation price,[23] instead of holding out with hope of extracting a greater share of the gains from trade in the aftermarket.[24] This is especially true since participating in a large-scale simultaneous auction would have low transactions cost relative to individually negotiating with potential buyers afterwards. The smaller the potential gains from holding out, the less likely that these gains will exceed the additional transaction costs of *ex post* negotiations.

As the scale of an auction increases, the incentive to participate also increases because buyers and sellers are more likely to find a match. Buyers would generally rather go to a large exchange than a small one because they are more likely to find the spectrum they seek. And sellers would rather participate in an exchange with lots of buyers because they are more likely to find a party that needs the spectrum they are selling. This may be one of the reasons for the continuing success of eBay. To the extent that there are such participation effects in spectrum

[23] A reservation price is the minimum price at which a seller is willing to sell.

[24] The aftermarket refers to spectrum license sales that occur outside of an FCC run auction.

markets, private parties may have difficulty organizing such markets.[25] Each market maker will wish to convince potential participants that it will have the largest exchange, but this cannot be true for everyone. These considerations may introduce a coordinating role for government in ensuring widespread participation by buyers and sellers.

3.7 Package Bidding

Package bidding, which allows bidders to make all-or-nothing bids on packages of licenses, without specifying prices for the individual licenses in a package, can increase the efficiency of a market mechanism when some items are highly complementary but parties disagree about the best way to package the pieces. (If everyone agreed on how to package items, the items should just be sold in those packages, like left and right shoes.) In such cases, package bidding facilitates efficient aggregation of spectrum across geography and bandwidth. Without package bidding, bidders face the "exposure" risk of getting stuck with only part of a desired aggregation and paying more than it is worth without the other parts.

To illustrate the advantage of package bidding, suppose license A or B alone is worth $50 to bidder 1, but together they are worth $150. If bidder 1 bids more than $50 on either license, it faces the risk of paying more than the license is worth if it doesn't also win the other license. This risk may prevent the bidder from winning a package of licenses even when it is efficient. Suppose bidder 2 values license A at $60 and bidder 3 values license B at $80. Also suppose that bidders 2 and 3 need only a single license and so place no incremental value on a second license. The efficient outcome is for bidder 1 to win both licenses, with a total value of $150, since this exceeds the combined value of $140 for bidders 2 and 3. With package bidding, bidder 1 could ensure this outcome by bidding $141 for the package AB. In contrast, without package bidding bidder 1 might win neither license because it is afraid to raise its bids above the $50 stand-alone value of each license.

Package bidding could also allow for the market to determine band plans. Currently, the FCC administratively determines the precise frequency spacing of spectrum licenses including whether spectrum should paired or unpaired and the degree to which block sizes and spacing in

[25] This is similar to bandwagon effects for networks, such as telephone service or the Internet, where the service is more valuable to a consumer the more other consumers use the service. *See* Rohlfs (2001).

the United States should match those in other countries. Licenses generally are composed of paired blocks on the assumption that licensees will employ frequency division duplex (FDD) technology that uses separate frequencies for base and subscriber transmitters. On the further assumption that licensees will agree to put all base stations in at one end of the paired spectrum and subscriber units at the other, less demanding limits on out-of-band emissions are needed than if bases and mobiles operate in adjacent spectrum. However, there is growing interest in a different duplexing technique, called time division duplex, or TDD, that uses the same spectrum for base and mobile transmissions and which may have unique advantages in certain kinds of services. Rather than predetermining which technology will be used by mandating a particular band plan and pairing scheme, the FCC could allow those choices to be made in the auction. Package bidding could provide for a market test of mutually exclusive band plans. Bidders could bid on two or more mutually exclusive band plans at the same time and the auction process would determine the single band plan that maximizes auction revenue.

Package bidding may also reduce the holdout problem. Without package bidding, sellers may be able to increase their revenue by exploiting the synergistic value of licenses. For example, the owner of license B in the above illustration might want to hold out until after bidder 1 has purchased license A. Regardless of what bidder 1 paid for license A, its gain from also acquiring license B is $100. (Suppose bidder 1 paid $61 for license A. If it paid $100 for license B, its net loss from A plus B would be $11, the same as if it held only A.) The seller of license B would like to get as much of this surplus a possible. But the seller of license A would have the an analogous incentive to holdout until bidder 1 has purchased license B. Bidders would want to avoid this trap and might choose not to participate in the auction at all. Package bidding helps solve this coordination problem. With package bidding, bidder 1 could make a bid up to $150 on the package AB without facing any risk of paying more licenses than they are worth to it. Bidder 1 would never need to commit itself to A without B, or B without A. If either A or B held out, the entire package would go unsold. And none of the sellers of the items in the package would be in the strategically advantageous position of being the lone holdout.

4 A Proposed Transition Market Mechanism: Band-Restructuring Auctions

The FCC has already achieved success in transitioning to a market allocation of spectrum in bands previously limited to point-to-point use, as in the case of PCS,[26] and is proceeding to do the same in the 700 MHz band for spectrum previously allocated to UHF television.[27] Our proposal in this paper builds on methods developed in those proceedings and seeks to improve and expand their use as a general transition mechanism. The improvements we propose are directed at using markets to accelerate the efficient clearing and restructuring of encumbered spectrum. The principal feature of our proposed transition market mechanism is a simultaneous large-scale two-sided auction, where incumbent participation is voluntary, but incumbents who choose not to participate forego flexibility for five years.[28]

4.1 Simultaneous two-sided auction with package bidding

A single large-scale two-sided auction for all exclusively allocated spectrum would help bidders to combine encumbered and unencumbered spectrum into efficient packages. It would also allow bidders to efficiently choose among substitutable spectrum licenses. In a simultaneous ascending bid auction,[29] as the price of a license or package rises relative to a substitute, a bidder can easily switch its bidding to the license or package that is a better value. And, it would help spectrum incumbents to relocate voluntarily to lower value spectrum when it is efficient to do so, by allowing them to sell and buy spectrum rights simultaneously.

Because of the nature of the current use in certain bands and for other reasons discussed in Section 5, it may not be feasible to include all spectrum licenses that are substitutes and/or

[26] See discussion in Crampton, Kwerel and Williams (1998), pp. 660-669. The PCS band was initially allocated for microwave systems providing wireless communications links among fixed points, as a substitute for wireline service.

[27] FCC (2001a, 2002)

[28] De Vany (1998) proposed a government-run two-sided auction to reallocate encumbered spectrum. Our proposal goes beyond De Vany's in that we would provide additional incentives for participation by making it a condition for flexibility and would facilitate greater band restructuring by offering unencumbered and encumbered spectrum in the same large-scale auction.

[29] An ascending bid auction is one in which prices always rise. An oral outcry, or English, auction is the most familiar example. In FCC simultaneous spectrum auctions multiple licenses are put up for auction at the same time, and bidding is permitted on all licenses until the auction closes.

complements in a single simultaneous auction with package bidding. There are also technical and operational limitations on the number of licenses that can be auctioned simultaneously. To date, the largest FCC simultaneous multiple round auction contained slightly over 15,000 licenses.[30] Providing for package bidding introduces additional limitations on auction scale. While the FCC is developing a large-scale package-bidding mechanism, the first FCC package-bidding auction is currently scheduled to contain only 12 licenses.[31] Moreover, providing for a two-sided auction may introduce additional constraints on the auction scale. This would be particularly true, if seller participation goes beyond allowing incumbents to offer and bid on their own licenses. If sellers are permitted to make specific offers of the prices at which they are willing to sell and lower those ask prices in the auction, new software would be required and additional technical constraints on auction scale would need to be considered.

One way to accommodate the technical and operational constraints on auction scale would be to conduct a series of auctions where the licenses that are the closest substitutes and complements are grouped within the same auction. This is the approach that the FCC has used to address technical limitations on auction scale and institutional/legal constraints on when various blocks of spectrum are available for auction.[32] Another option would be to run several simultaneous two-sided package-bidding auctions in parallel. While this reduces computational difficulties that grow with the scale of package bidding auctions, it creates operational concerns for the FCC, which has limited staff with experience conducting an auction, especially one with a novel design.

Where there are very large numbers of licenses that are close substitutes but without strong complementarities, the FCC might wish to use a simultaneous auction without package bidding. Here the gain from grouping the licenses in a single simultaneous auction would outweigh the loss from not offering package bidding. On the other hand, when there are very strong complementarities among certain licenses for some, but not all, bidders, the benefits of offering

[30] FCC auction # 40 for paging licenses was conducted 10/30/2001-12/5/200 with 15,514 licenses. *See* http://wireless.fcc.gov/auctions/summary.html#completed.

[31] FCC auction #31for upper 700 MHz band licenses has been postponed with no date yet scheduled.. http://wireless.fcc.gov/auctions/31

[32] *See* Kwerel and Rosston (2000).

package bidding may outweigh the loss from somewhat limiting the scope of the auction.[33] Another compromise is to define larger licenses so that it is feasible to auction more of them simultaneously. Smaller licenses provide bidders more flexibility in grouping spectrum across geography and bands, if the licenses can be auctioned together. But if so many licenses are created that they must be auctioned in separate groups, bidders lose the benefits that simultaneity provides for aggregating or substituting among licenses.

Even if it appeared technically feasible to offer all spectrum in a single two-sided simultaneous auction with package bidding, using a new mechanism for so much spectrum would expose the FCC and auction participants to an unacceptable risk of an operational or design flaw. Thus we propose that the FCC initially implement the mechanism on a smaller scale. This was the approach used for the initial FCC spectrum auctions.[34]

Further study of the best design of a simultaneous exchange mechanism is necessary. An operationally simple approach would be to use the FCC's one-sided package bidding auction design and treat the licenses of incumbents like any other license in the auction. Sellers of licenses would look like any other bidder during an auction, except that no payment would be owed if they win one of their own licenses. Allowing sellers to bid on their own licenses should not distort the outcome of the auction any more than allowing them to set a reserve price prior to the auction, provided that the identities of all bidders are revealed during the course of the auction.[35] In ascending bid auctions where the identities of bidders are kept secret, such as art auctions, sellers are forbidden from bidding but are able to set secret reserve prices. Presumably, the ban on "shills" is to assure buyers that there is at least one other party willing to pay the highest losing bid. This simple extension of the FCC one-sided auction design may not ensure

[33] If all bidders agreed on the best way to package spectrum, then the FCC should offer the spectrum in those packages and there would be no benefit from package bidding. There is no reason to sell left shoes and right shoes separately if everyone wants them in a package. Only if some people find the package much more valuable than the sum of parts and others do not or want to form a different mutually exclusive package, is there a benefit to package bidding.

[34] Nationwide Narrowband PCS was held 7/25/1994-7/29/1994 with 10 licenses; Regional Narrowband PCS was held 10/26/1994-11/08/1994 with 30 licenses; and A & B Block PCS was held 12/5/1994-3/13/1995 with 99 licenses. *See* http://wireless.fcc.gov/auctions/summary.html#scheduled, and Kwerel and Rosston (2000).

[35] Sellers would have an incentive to bid up the prices of the licenses they are selling. The incentives are the same as for setting a reserve price prior to the auction. A seller would seek to raise the license price above its personal valuation, but not above the valuation of the bidder with the highest valuation. As with any reserve price, there is some chance that it will exceed the highest valuation and thus result in a loss of efficiency. *See* Riley and Samuelson (1981, 385).

efficiency in the supply of spectrum, *e.g.,* that licenses are sold by those parties that value them the least. To promote an efficient allocation with multiple sellers it may be necessary to provide for explicit ask prices, *i.e.*, the minimum price a seller is willing to accept for an item, and determine the winners as the set of bids and asks that maximizes surplus. [36]

4.2 Voluntary participation is the quid pro quo for flexibility

Incumbents that participate in a band-restructuring auction would gain the right to convert the spectrum they encumber to flexible use. They would be able to exercise their new flexible use rights in different ways, depending on the nature of their current licenses. Incumbents with exclusive area licenses, *e.g.*, broadcasting and ITFS licenses, would gain flexible use rights within their current service area and spectrum subject to boundary power limits and restrictions needed to protect other incumbents' current use. Incumbents that do not have defined service areas (*e.g.*, fixed point-to-point licenses) would have the right to free-up additional spectrum for flexible use for an area licensee by voluntarily terminating operation or reducing their interference protection rights. All participating incumbents would be allowed to continue their current uses and receive the same interference protections they now have.

While incumbent participation would be purely voluntary, making it the *quid pro quo* of flexibility would provide an incentive for all to participate.[37] An incumbent that chooses not to offer spectrum in a band-restructuring auction could continue to use its spectrum under current rules, but for five years, must forego the flexibility that participants are granted.

To prevent subversion of the five-year waiting period, the FCC may need to impose additional restrictions on post-auction transactions that involve the spectrum encumbered by non-participating incumbents. For example, it should be clear that the five-year waiting period applies to the encumbered spectrum even if the incumbent cancels the associated license. Other

[36] See section 4.4. Operationally, the current auction design could be extended to an exchange by treating ask prices of sellers as negative bids. Raising a negative bid would be equivalent to lowering the ask price. Sellers would receive payments and buyers would make payments. Maximizing revenue would be equivalent to maximizing surplus (bids minus asks). Further research is needed as to what other auction rules (*e.g.*, activity and minimum acceptable bid) would need to be modified.

[37] Providing for such an incentive to participate may make it possible to design an exchange that is both efficient and voluntary (individual-rational) without violating the Myerson and Satterthwaite (1983) impossibility theorem, since the exchange is not also budget-balanced.

safeguards might include requiring FCC pre-approval of any agreements to reduce the protections of spectrum subject to the waiting period or of any new facilities that would degrade such protections. These restrictions, as well as the waiting period itself, are needed only as a deterrent to speculative holdout, and would not impose significant costs if, as expected, all or most of the incumbents agree to participate.[38] However, for incumbents who do not participate, rigorous enforcement of the waiting period and other restrictions would be necessary (even recognizing the resultant efficiency loss) to maintain the integrity of the rule as a deterrent to holdouts in subsequent auctions. At the end of the five-year waiting period, incumbent licenses that were not offered in the auction would convert automatically to flexible use, as if they had participated in a band-restructuring auction.

If an incumbent chooses to sell its license it would keep the proceeds. If the license is part of a package that includes licenses held by more than one seller, the revenue for the package is divided according to a formula, *e.g.*, the share of spectrum (MHz-pops) in each license. The choice of formula is discussed in Section 4.4.

Incumbents who sell their licenses would clear their spectrum within a FCC specified time period, possibly one year, following the auction. Licenses that provide for exclusive use within an actual or implied service area would transfer to the new owner and convert to flexible use after the period. Any existing uses of such licenses by incumbents would terminate at that time. Incumbent licenses that do not have service areas or operate in shared bands would cancel automatically at the end of this period to clear spectrum for flexible use by area licensees.

Incumbents will, of course, take into account their clearing costs in deciding whether to sell their licenses in the auction. License winners and sellers would be free to negotiate after the auction about changing the deadline for clearing existing uses. Allowing incumbents and bidders to specify different clearing periods within the auction might also be considered, if such additional complexity can be accommodated. This would increase the efficiency in the clearing schedules especially if clearing costs differ greatly across licenses and do not decrease

[38] We believe that making flexibility conditional on participating, plus the benefit of selling in a simultaneous exchange, would strongly discourage strategic holdouts. However, if this turns out not to be the case, the FCC could require additional measures such as giving flexible overlay licensees the right to clear holdouts with payment of compensation. *See*, Cramton, Kwerel and Williams (1998).

proportionally to the clearing time. It would facilitate efficient adjustments in clearing schedules and allow better matching of buyers and sellers according to preferred clearing dates.

Spectrum encumbered by multiple licenses would not be available for flexible use for the five-year waiting period unless all the licensees agreed to participate in a band-restructuring auction. For example, analog TV licenses on channels 59 and 61 in an area adjacent to a channel 60 assignment would encumber channel 60 spectrum over some part of the channel 60 licensee's service area. So channel 60 would not be available for flexible use throughout that licensee's service area unless licensees for channels 59 and 61 also participated in the auction. This should not be a serious problem, since it is rational for all incumbents to participate.

4.3 An incumbent need not sell its license

Incumbents who offer spectrum in a band-restructuring auction would not be required to sell their licenses. A seller could "buy back" its license(s) at no net cost to itself and still gain the rights to flexible use. Even if a license is not sold, something socially useful would be gained by inducing participation in the auction. Participation makes the implicit opportunity cost of holding a license explicit.[39] Once an incumbent is participating in a band-restructuring auction it is unlikely that top management would completely delegate the decision of whether to keep or sell highly valuable licenses. It is difficult to imagine, for example, that managers in charge of spectrum-based communications systems would be able to buy back licenses for 500 million dollars without approval of top management.

It is not obvious, however, if this approach would completely overcome principal-agent conflicts with respect to the initial decision to participate. Since participation costs are likely to be very low and incumbents need not sell their licenses to get valuable flexibility, all rational incumbents should participate. But it is possible that spectrum managers, whose primary interest is preserving their positions, might make the initial decision about whether to participate. This difficulty could be overcome if the band-restructuring auctions were publicized sufficiently. One advantage of a FCC sponsored transition is that it would likely get extensive press coverage.

[39] Our simplified two-sided exchange mechanism would not face buyer or sellers with the precise opportunity cost of their transactions. Only a Vickrey (1961)-Clarke (1971)-Groves (1973) mechanism for a combinatorial exchange would do this.

4.4 Efficient and fair division of auction proceeds

In exchange for participating in the band-restructuring auction, incumbents would receive a portion of the auction revenue. The rules for dividing revenues affect both the efficiency and the fairness of the auction, and further study of the best payment mechanism is needed. For sales of individual licenses or licenses that are part of a package with a single seller, the seller would receive the entire amount of the winning bid. But for licenses that are part of a package with multiple owners, a method is needed to divide up the winning bid among the sellers. A simple and plausibly fair mechanism might award to each seller the fraction of the winning bid for the package given by the ratio of MHz-pops encumbered by its licenses to the total MHz-pops in the package. This mechanism may also have certain desirable efficiency properties since it eliminates the incentive for sellers to engage in strategic behavior designed to increase their share of the winning bid on a package. Some adjustment in the MHz-pop value may be appropriate to account for factors other than population that may affect spectrum values between urban and rural areas. MHz-pops encumbered by a single licensee would be attributed entirely to that licensee. MHz-pops encumbered by two or more licenses would be divided equally among those licensees. Unencumbered MHz-pops (*i.e.*, the "white space" held by the FCC or NTIA) would be attributed to the United States treasury.

Alternative payment formulas should be considered that better account for seller valuations. Dividing revenues in proportion to MHz-pops might not create sufficient incentive to sell a license in an auction when it is efficient to do so. For example, suppose an incumbent holds a 1 MHz license, A, that it values at $1, and the FCC holds a 99 MHz license, B, that has a reservation price of $25. Assume that bidder 1 values the package AB at $75 and that bidder 2 values license B alone at $50. Awarding the package AB to bidder 1 maximizes surplus ($49 compared to $25 if B is awarded to bidder 1 and the incumbent keeps A). If package AB were sold for $75 and revenues divided in proportion to MHz-pops, $.75 would go to the incumbent on license A and the rest to the treasury. But the incumbent would not sell license A for $.75. It could bid $26 for A so that its bid combined with bidder 2's bid of $50 would beat bidder 1's bid. This result would be inefficient. Bidder 1 might acquire the package AB in the aftermarket, but would incur additional transaction costs and lose the benefits of a simultaneous auction design.

Such an inefficient outcome is unlikely if relative license valuations are approximately proportional to MHz-pops and the value of licenses in flexible use is significantly greater than the value in the current use. The simple revenue division formula may be adequate for the initial applications of the proposed band-restructuring auction because the gap between value in current use and flexible use is likely to be quite large.

While more complex, an auction design that allows sellers to explicitly set ask prices might more accurately assign package value to individual components. Parkes, Kalagnanam, and Eso (2001) have proposed a promising payment scheme in the context of a sealed bid combinatorial exchange. They propose an approximation of the (efficient) Vickrey payments that ensures budget balance for the exchange (total payments to sellers do not exceed total receipts from buyers). It may be possible to extend such a "second-best" payment rule to a simultaneous ascending bid combinatorial exchange.

4.5 FCC conducted band restructuring auctions

We believe the FCC should conduct the proposed band-restructuring auctions. The FCC is in the best position to solve the *coordination problem* of putting highly interdependent spectrum up for auction at the same time. The FCC already holds unencumbered spectrum that is complementary with encumbered spectrum. The FCC already has established credibility in auctioning spectrum licenses. Because the FCC has the most tools to address the incentive problems, it is best able to help ensure that there will be a high level of participation.

The FCC is also in the best position to solve *incentive problems* associated with ensuring participation and mitigating holdout problems. FCC regulatory authority over spectrum gives it more "carrots" and "sticks" than private parties. Because the FCC is best able to solve the coordination problem of ensuring a large-scale auction, it has an advantage in solving the incentive problems. As discussed above, as the expected scale of the auction increases, both buyers and sellers have a greater incentive to participate, and sellers have less incentive to strategically holdout.

Finally the FCC has certain real cost advantages in running a band-restructuring auction. Permitting incumbents to sell their licenses in a FCC auction along with FCC held spectrum would add relatively little cost.

Nevertheless, if the FCC concluded that conducting two-sided band-restructuring auctions is not legally or politically feasible, then other options should be considered that permit simultaneous aggregation of the entire spectrum in a band. One option would be to rely on a privately run simultaneous auction for the new overlay licenses as well as the incumbents' rights. This would effectively privatize the FCC's auction process, and measures would be required to ensure that the design and conduct of the private auction was fair and efficient and that the Treasury receives its share of the proceeds. It is not obvious whether a private party could successfully run such a large-scale band-restructuring auction. What happens if multiple firms wish to run an auction for the same spectrum? Could the FCC delegate the sale of FCC held spectrum to the party holding such an auction? How would the FCC choose among multiple parties wishing to sell the same FCC held spectrum, acting as its agent? Should the FCC hold an auction for that right? How long would it take for the private sector to resolve who would run such an auction? If highly interdependent spectrum is not put up for auction simultaneously there could be a large efficiency losses, especially during the initial transition (when restrictions on flexibility are removed) because of the magnitude of the current misallocation. Transaction costs could be high and efficiency-enhancing trades not occur without a well-organized centralized exchange. Such institutions may develop over time, as did the New York Stock Exchange and the Chicago Commodity Exchange. Although that may happen with spectrum as well, the cost of a long transition could be great.

5 What Spectrum Should be Restructured?

As we have indicated, to maximize allocation efficiency across substitutable and complementary spectrum, each auction should cover as wide a frequency range as possible and include as much spectrum within that range as possible. However, there are difficult design and implementation issues with very large auctions. Complexity of auction software is a problem for very large auctions with package bidding. In addition to auction complexity constraints, it is not clear how incumbents would make voluntary participation decisions in many bands. For example, how would incumbents with non-exclusive spectrum assignments, as in the traditional private land mobile bands, collectively decide whether to clear a band? Even where incumbents have exclusive spectrum assignments, questions arise as to the appropriate entity to make decisions on selling or buying spectrum. Should we rely on DOD and public safety agencies, for

example, to offer spectrum presently limited to those uses? Should individual broadcasters be able to convert spectrum to non-broadcast use, or should consumers of broadcast services or the FCC have a say? Who decides on the sale of navigation spectrum used in the U.S. by foreign and domestic vessels?

We believe these issues are not insurmountable, allowing most spectrum to be restructured over time with auctions. But we also believe the technique can and should be implemented initially on a more limited scale both to test the concept and to provide much needed relief to immediate spectrum shortages. Our specific proposal, discussed below, would restructure 438 MHz of very desirable spectrum for market allocation within a relatively short 2 to 5 year time frame.

5.1 300 MHz to 3000 MHz

Spectrum in the 300 MHz to 3000 MHz range is sometimes referred to as "Beachfront Property" since it is the frequency range most in demand for high valued, high growth uses such as 3rd generation cellular mobile services (3G). Because of the high value of spectrum in this range, the economic gains from an efficient allocation would be particularly great. We believe that this range is the logical place to initiate band-restructuring auctions. We note, however, that efficient restructuring of spectrum in the 300 MHz to 3000 MHz range would benefit greatly from the inclusion in the same auction of spectrum above 3000 MHz that could be simultaneously acquired as replacement spectrum by incumbents wishing to sell more valuable spectrum in the lower range. Therefore, as our analysis continues, we hope to be able to amend our initial implementation proposal to include complementary bands in the higher frequency range, either in the same auction or in a separate, simultaneous auction.

Spectrum in the 300 MHz to 3000 MHz range can be considered approximately fungible for most uses, with the lower frequencies benefiting from somewhat lower cost technology and reduced propagation loss. The substitutability of frequencies across the range suggests restructuring the entire band in a single, simultaneous auction. However, we do not believe such a large auction event is either feasible or advisable as an initial implementation of the concept. We must therefore narrow the options. In the remainder of this section, we develop a rationale for identifying bands within the 300 MHz to 3000 MHz range that present what we believe to be

manageable implementation issues and yet provide substantial bandwidth. We are looking for bands that can be restructured within two to five years. This is soon enough to address current spectrum shortages while providing adequate planning time to complete the necessary rulemaking and auction development.

5.2 Eliminating difficult bands from the initial implementation

Different categories of bands within the 300 MHz to 3000 MHz range pose very different implementation problems of the kinds mentioned earlier in this section. Excluding categories of bands that present the most difficult problems would thus seem a rational method for narrowing the options for initial implementation. The results of this analysis are presented in Figure A which we will explain more fully below.

Figure A is a band-by-band graphical representation of the US Allocation Table from 322 MHz to 3100 MHz, a total of 2778 MHz. There are 124 separate bands in Figure A, ranging in size from 255 MHz to 0.1 MHz. The vertical frequency bar in the table is drawn on a linear scale (approximately), which is why the labeling of many of the smaller bands is not clearly legible.[40] The frequency limits of each band are displayed in Column A and the bandwidth is identified in Column B. Color shading indicates whether a band is allocated to government only (red), non-government only (blue) or both government and non-government (green). Unlicensed bands (yellow) and bands recently transferred from government to non-government (violet) are identified separately.[41] A general description of the uses of the various bands is also presented in the far right column, although readers should refer to the FCC's online allocation table for the official designations.[42]

The analytical approach we use narrows options through a process of elimination by progressively applying filters to exclude bands that we believe would not be good candidates for initial restructuring auctions (Columns C through F) and bands that are presently structured by market forces, *i.e.*, are flexibly allocated and exhaustively assigned (Column G). From the bands

[40] An expanded version of the chart used to create Figure A is posted on the OPP website at http://www.fcc.gov/Bureaus/OPP/working_papers/oppwp38chart.pdf.

[41] For a listing of bands recently transferred from government to non-government use, *see* NTIA (2001), para. 10.

[42] http://www.fcc.gov/oet/spectrum/table/fcctable.pdf.

FIGURE A

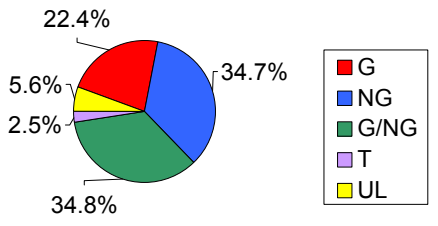
ANALYSIS OF POTENTIAL SPECTRUM FOR INITIAL BAND-RESTRUCTURING AUCTIONS (322 MHz to 3100 MHz)

BAND (MHz)	ALL BANDS (BANDWIDTH IN MHz)	CATEGORIES OF BANDS EXCLUDED (Bands excluded by each category show up as increased white space in the spectrum chart under that heading relative to the column to its immediate left)					BANDS PROPOSED FOR INITIAL RESTRUCTURING AUCTIONS (1710-1755 MHz added in text)	GENERAL SERVICE DESCRIPTION (NOTE: Service names used on this page are the authors' own derivations and not necessarily official FCC terminology.)
GOVERNMENT / NON-GOVERNMENT / GOVERNMENT AND NON-GOVERNMENT / TRANSFER / UNLICENSED		EXCLUDE G, G/NG AND T BANDS	EXCLUDE CORE TV BANDS	EXCLUDE UNLICENSED BANDS	EXCLUDE PRIVATE LAND MOBILE AND GUARD BANDS	EXCLUDE PRESENTLY FLEXIBLE BANDS		
A	B	C	D	E	F	G	H	
335.4-399.9	64.5							FIXED, MOBILE, SATELLITE, NAVIGATION, WEATHER AIDS (322-450 MHz)
420-450	30							
450-470	20							PRIVATE LAND MOBILE (450-470 MHz)
470-512	42	42						
512-608	96	96						CORE UHF TV BAND CHANNELS 14-51 *Excluding Ch. 37.* (470-698 MHz)
614-698	84	84						RADIOASTRONOMY
698-746	48	48	48	48	48	48	48	REALLOCATED TV CHANNELS 52-59 - *"Lower 700 MHz"* (698-746 MHz), Possible 3G
746-762	15	15	15	15	15	15	15	
764-776	12	12	12	12				REALLOCATED TV CHANNELS 60-69 - *"Upper 700 MHz"* (746-806 MHz), Possible 3G
776-792	15	15	15	15	15	15	15	
794-806	12	12	12	12				
824-849	25	25	25	25	25			CELLULAR, Possible 3G
869-894	25	25	25	25	25			CELLULAR, Possible 3G
902-928	26	26	26					UNLICENSED BAND
928-944	16	16	16	16	16	16		FIXED, MOBILE
960-1215	255							NAVIGATION
1215-1240	25							GPS (1227.6 MHz)
1240-1300	60							RADAR
1300-1350	50							NAVIGATION
1350-1390	40							FIXED, MOBILE, RADAR, NAVIGATION (GPS 1381.05 MHz)
1390-1392	2							TRANSFER BAND
1400-1427	27							WEATHER AIDS
1427-1435	8							TRANSFER BANDS
1435-1525	90							AERONAUTICAL TELEMETRY
1525-1540	15							L-BAND MSS DOWN LINK (Possible 3G)
1540-1559	19							GPS (1575.42 MHz)
1559-1610	51							SATELLITE, WEATHER AIDS, RADIOASTRONOMY, NAVIGATION
1610.6-1626.5	15.9							L-BAND MSS UP LINK (Possible 3G)
1626.5-1645.5	19							TRANSFER BAND
1645.5-1660.5	15							WEATHER SATELLITES
1675-1700	25							TRANSFER BAND (Possible 3G)
1710-1755	45							GOVERNMENT FIXED AND MOBILE (Possible 3G)
1755-1850	95							PCS (Possible 3G)
1850-1910	60	60	60	60	60			UNLICENSED PCS (Possible 3G)
1910-1930	20	20	20					PCS (Possible 3G)
1930-1990	60	60	60	60	60			2 GHz MSS UPLINK (Possible 3G)
1990-2025	35	35	35	35	35	35	35	SPACE, FIXED, MOBILE (BROADCAST AUXILIARY)
2025-2110	85							FIXED AND MOBILE (Possible 3G)
2110-2150	40	40	40	40	40	40	40	2 GHz MSS DOWNLINK (Possible 3G)
2150-2160	10	10	10	10	10	10	10	FIXED, MOBILE, SATELLITE
2165-2200	35	35	35	35	35	35	35	TRANSFER BAND
2200-2290	90							WCS
2290-2300	10							SDARS
2300-2320	20	20	20	20	20			WCS
2320-2345	25	25	25	25	25	25		TRANSFER BAND
2345-2360	15	15	15	15	15			(Possible 3G)
2360-2385	25							UNLICENSED BAND
2385-2402	17	17	17					
2402-2417	15	15	15					
2417-2450	33	33	33					
2450-2483.5	33.5	33.5	33.5					
2483.5-2500	16.5	16.5	16.5					
2500-2655	155	155	155	155	155	155	155	MDS - ITFS (Possible 3G)
2655-2690	35	35	35	35	35	35	35	
2690-2700	10							
2700-2900	200							NAVIGATION
2900-3100	200							
COLUMN TOTALS	2778	1120.97	898.97	742.97	661.5	461.5	393	
% OF TOTAL	100.0%	40.4%	32.4%	26.7%	23.8%	16.6%	14.1%	

Including the1710-1755 MHz band, the total spectrum proposed is 438 MHz.
(See text for explanation)

FIGURE B

GOVERNMENT / NON-GOVERNMENT DIVISION OF SPECTRUM IN THE 322-3100 MHz RANGE (Secondary Allocations and Footnote Provisions Not Counted)



G	NG	G/NG	T	UL	TOTAL
621.6	965	965.4	70	156	2778
22.4%	34.7%	34.8%	2.5%	5.6%	100.0%

remaining in Column G, we identify in Column H a collection of relatively large bands totaling 393 MHz that appear to be good candidates for the initial restructuring auction. These are the lower and upper 700 MHz bands 698-746 MHz, 747-762 MHz and 777-792 MHz (78 MHz) recently reallocated from television broadcasting ; the 2 GHz MSS bands 1990-2025 MHz and 2165-2200 MHz (70 MHz); the 2110-2165 MHz non-government general fixed and mobile band (55 MHz); and the 2500-2690 MHz ITFS/MDS band (190 MHz). To these bands we suggest adding the 1710 MHz to 1755 MHz government transfer band (45 MHz) bringing the total spectrum to be restructured in our proposal to 438 MHz. If a more limited initial roll-out is preferred, we suggest the 2 GHz MSS bands and the ITFS/MMDS band as potential candidates. We now explain our reasoning behind these choices more fully.

Federal government spectrum

The first filter in Table A (Column C) eliminates all bands that are allocated either for exclusive federal government use or for shared government/non-government use, even if they have been identified as bands to be transferred to non-government use (transfer bands) or identified for possible 3G use. Restructuring spectrum not under exclusive FCC jurisdiction will be particularly difficult, requiring concurrence by the NTIA and potentially other government agencies now operating in those bands.

Another problem is participation. Government incumbents may not have strong incentives to participate in the auction, and may require more complex band clearing agreements. To maintain essential missions, government agencies may require longer periods to clear spectrum or contingency clauses that permit spectrum to be reclaimed in emergencies. While we believe these more complex arrangements can be worked out, we do not believe it is possible to do so within our two to five year time frame. Therefore we have eliminated government and shared bands from consideration for initial band-restructuring auctions.[43] Deleting government and shared bands reduces the spectrum total by approximately 60 %, as shown in the column totals at

[43] Because of participation problems with government incumbents, we have also excluded the so-called "Transfer Bands," *i.e.*, bands that have been identified for reallocation to non-government uses but which will continue to be encumbered by government systems for several years. However, in our final proposal we recommend including the largest of these bands, the 1710-1755 MHz band, in the initial proposal because of it size and potential complementarity for pairing with other spectrum in our proposal. It also appears that the band clearing rules for that band significantly reduce the need for incumbent participation in the auction. *See*, NTIA (2001).

the bottom of the chart. For greater clarity on this point, we have included a special insert (Figure B) showing the government/non-government division of spectrum in the range.

In the longer run, excluding the large amount of spectrum presently reserved for government use would significantly reduce the efficiency gains from a transition to a spectrum market. In principal, we think that government users should acquire spectrum at market prices the same way they acquire other inputs such as oil, real estate and computer equipment. Paying market prices for these other inputs does not diminish the quality of government services. Moreover, in the transition to a market system, government spectrum users are likely to be net sellers of spectrum, creating an initial cash surplus above the cost of replacing their current wireless communications services. This surplus could be used to increase public services. It would be beneficial if public sector spectrum could be offered simultaneously with complementary and substitutable spectrum now allocated to commercial use because this would facilitate value-enhancing trades between the two sectors.

If included, government spectrum would be treated much like private sector spectrum is treated: the unassigned portions would be offered in the form of overlay licenses and incumbents would be invited to offer their spectrum and set reserve prices by bidding in the auction. The incentives for participation by public sector incumbents might be weak, however, even with the potential for significant cash surplus. For this reason, the decisions about whether to sell or retain existing public sector spectrum should be made at an organizational level high enough to make the appropriate tradeoffs between the benefit of the spectrum to the organization and the benefit of other goods and services that could be obtained with the cash received by selling the spectrum. For spectrum used by the federal government, perhaps only Congress could make this decision. As a practical matter, Congress would need to delegate the authority to decide whether to keep or sell federal government spectrum in the band-restructuring auctions, but would need to take care that it does not create a principal-agent problem by delegating down to too low a level. [44]

[44] The same logic holds for non-federal public safety spectrum. In that case, the appropriate authority for deciding participation might be the state governments, perhaps the governors, who have functional responsibilities that cut across a broad range of public services, including safety services. We note that the FCC has designated 2.4 megahertz of the Public Safety 700 MHz band as state channels. *See*, FCC (2001b).

Core TV spectrum

In Column D we eliminate the bands generally known as "core" TV spectrum, *i.e.*, 470 MHz to 698 MHz. Some of this spectrum might eventually be made available for market allocation and subject to a restructuring auction. However, considerable TV spectrum has recently been reallocated for other uses in the lower and upper 700 MHz bands (previously TV channels 52 to 69).[45] Considering the political sensitivities associated with broadcast spectrum and maintenance of free over-the-air television, we do not foresee further reduction of the core TV band within our time frame. Thus, we are not proposing to include any of the core TV spectrum in initial band-restructuring auctions. Eliminating this spectrum removes another 8% of the spectrum from consideration.

We would note, however, that there may be a more efficient way to maintain a minimum level of free television service while allowing additional spectrum to be restructured for market allocation. One approach might be for the FCC to auction flexible overlay licenses covering the entire core TV spectrum and allow incumbent broadcasters to offer their spectrum for sale in the same auction with the caveat that they each continue to offer at least one free over-the-air standard-definition program stream in digital format. Since as many as six standard definition program streams can be provided on a single digital channel, this could make most of the current TV spectrum available for flexible use. Even if each program stream were provided in high definition, the greater interference immunity of the DTV format coupled with possible co-location of transmitters could greatly reduce the amount of spectrum required.

Unlicensed bands

The third filter (Column E) removes unlicensed bands. Restructuring unlicensed bands solely through the use of an auction does not appear feasible. Since users of unlicensed bands have no exclusive rights and there is generally no record of the current incumbents (users) to whom such rights might be assigned, participation in an auction would not seem feasible. Any restructuring of unlicensed bands will probably require an administrative solution. Moreover, as discussed in section 2.5, setting aside some spectrum for low power, unlicensed use is probably efficient. We therefore propose to exclude current unlicensed bands, accounting for 6% of the total spectrum in the range. We also propose no change in the current provisions for unlicensed

[45] FCC (2001a., 2002)

use in licensed bands. The FCC would continue to manage those provisions and any potential interference from such devices would have to be taken into account by those who bid for spectrum licenses in adjacent bands.

While we are not proposing to include present unlicensed bands in initial restructuring auctions, such auctions might be a source of additional spectrum for similar kinds of devices as an alternative to administrative allocations. Future expansion of dedicated spectrum for unlicensed use could be obtained through negotiation between the manufactures of such devices and spectrum licensees. One possible arrangement would be for a licensee or group of licensees covering a particular band throughout the U.S. to charge manufacturers a fee for the right to produce and market devices to operate in that band. Such contracts could provide different grades of access for different fees, thus providing for a wider range of uses than are possible under the current rules. Competition between licensees would ensure that fees reflect the opportunity cost of the spectrum. Alternatively, manufacturers of low power devices might form a bidding consortium to acquire additional spectrum in our auction. If there is a continued desire as a matter of public policy to provide spectrum for such devices on a "free" basis, the FCC itself might purchase the spectrum in the auction, essentially reducing overall proceeds to the Treasury.[46] This would have the advantage of making the opportunity cost of such allocations more explicit.

Non-exclusively licensed bands and bands with many small licenses

The fourth group of bands eliminated by our filtering process (Column F) are bands in which incumbents do not have exclusive rights and the bands recently licensed as so-called "Guard Band Managers." Elimination of these bands removes another 3% of the spectrum.

The Guard Band Manager bands are excluded because of constraints on flexibility imposed to protect the adjoining public safety bands.[47] Since these bands were exhaustively and exclusively licensed by auction, they will have already been efficiently structured by market forces within the constraints imposed on flexibility. We assume these constraints will remain in

[46] Allowing this may require specific legislation.

[47] FCC (2000)

place to protect the public safety uses in adjacent bands, and thus see little to be gained by a restructuring auction.

The non-exclusively licensed bands (primarily those now designated for private land mobile use, including certain public safety bands) present special problems for participation in a restructuring auction. A voluntary participation rule, such as we propose, would require that all users who share a particular range of spectrum participate and agree to sell before that spectrum can be cleared. Participation by individual incumbents would be discouraged by the low likelihood that all incumbents would ultimately agree. Also, the amount of spectrum encumbered by any single licensee in a shared band may be too small to justify the cost of individual participation. This latter problem could also occur in exclusively licensed bands if the spectrum assigned to individual licensees is very small.

One possible solution in both cases may be to select a single entity to serve as an auction agent to participate on behalf of all incumbents in the band. Such an agent might be appointed by the FCC, as it has done with certain coordinators, or elected by a majority vote of incumbents. As with individual licensees, an agent could make both sell and buy decisions for the licensees it represents. It may be that the spectrum in a shared band has unique value because of its proximity to other bands. If so, some of the surplus from the sale of a shared band might be used to buy replacement spectrum for the incumbents in a lower cost frequency range. We believe the time required to solve these problems puts the time frame for restructuring of non-exclusive bands too far in the future for them to be considered for initial implementation of our proposal.

Currently flexible spectrum

Within remaining spectrum, bands that are presently allocated for flexible use (*e.g.*, cellular and PCS bands) are eliminated in column G, leaving 461.5 MHz. We see no need to restructure bands that are already allocated by market forces. Incumbents in these bands might be invited to offer their spectrum in the initial restructuring auctions of nearby bands, but would not, of course, be subject to the 5 year waiting rule since they already have flexibility. These bands account for 7% of the spectrum in the range.

Other bands excluded from initial implementation

Having eliminated approximately 83% of the spectrum in the range, we are left with the bands listed in Column G, a total of 461.5 MHz. Many of these remaining bands, *i.e.*, those in the 806 MHz to 960 MHz range, are too small and fragmented to be of much interest and would not pass our "substantial benefit" test. Also, while including the SDARS band 2320 MHz to 2345 MHz makes sense as a matter of principle, the apparent success of that service makes it less likely to change use in a restructuring auction. Therefore, we are not counting it in our total, although we do not dismiss it entirely as a possibility.

5.3 Our proposal - 438 MHz of additional spectrum for market allocation

If the SDARS and small bands are eliminated, what remains is a group of relatively large bands totaling 393 MHz that we believe are prime candidates for an initial band-restructuring auction, or series of auctions, such as we propose. These bands are shown in Column H. Specifically, they are: the lower and upper 700 MHz bands recently reallocated to flexible use from television broadcasting (698-746 MHz, 747-762 MHz and 777- 792 MHz, totaling 78 MHz); the 2 GHz MSS bands (1990-2025 MHz and 2165-2200 MHz, totaling 70 MHz); the ITFS/MMDS band (2500-2690 MHz, totaling 190 MHz); and the general and fixed mobile band (2110-2165 MHz, totaling 55 MHz). In addition to the bands selected in Column H, we propose to add the 1710 MHz to 1755 MHz government transfer band (45 MHz), bringing the total in our proposed initial restructuring auction to 438 MHz. This spectrum is technically suitable for a variety of potentially high-demand uses, and quickly restructuring it into an efficient market allocation could greatly increase its value to the economy. We discuss each band in turn.

The 700 MHz bands.

The upper and lower 700 MHz bands (698-746 MHz, 747-762 MHz and 777- 792 MHz, totaling 78 MHz) is spectrum recently reallocated to flexible commercial use from television broadcasting service. The bands were taken from what was formerly TV channels 51 to 69.[48] All of this spectrum is heavily encumbered and would therefore be a good candidate for an initial

[48] Another 6 MHz was reallocated as commercial Guard Bands to protect public safety users and, for reasons we have discussed earlier in this section, is excluded from our consideration for the proposed band-restructuring auctions. *See*, http://wireless.fcc.gov/auctions/summary.html.

restructuring auction. Eighteen MHz in the lower band has already been auctioned, while the remaining 60 MHz has not. All of this spectrum is heavily encumbered and could be considered as close substitutes if offered in simultaneous auction event. Thus, we propose that all 78 MHz be included in the initial band-restructuring auction. This would include the 60 MHz of unauctioned spectrum, 30 MHz in the upper 700 MHz band and 30 MHz in the lower band, as well as the 18 MHz in the lower band that has already been auctioned. In the latter case, the incumbent broadcasters as well as the new flexible licensees in the band would be invited to participate.

To provide incentives for the UHF TV incumbents in the unauctioned bands to participate in the two-sided auction, we would make flexibility conditional on participation. Under this proposal spectrum in these bands encumbered by a broadcaster who does not participate would remain restricted to broadcasting service until the end of the digital transition as specified by statute.[49] This restriction would apply whether or not the non-participating incumbent continues to broadcast or cancels its license. This incentive to participate would not apply to incumbents (broadcasters and flexible licensees) in the bands that have already been auctioned, who would remain subject to the rules currently in place for those bands.[50] We believe licensees in these bands would also have an incentive to participate in the auction. In this way all of the commercial spectrum in these bands could potentially be restructured in a simultaneous auction event.

The ITFS/MMDS bands.

In the ITFS/MMDS band, the FCC has added mobile as a permissible use that can be employed by incumbent licensees, but has not yet proposed the necessary interference and coordination rules. To implement our restructuring auction proposal in the ITFS/MMDS band, we recommend the following steps: (1) define explicit interference protection rights for incumbents, both ITFS and MMDS licensees; (2) reallocate the entire band (2500 MHz to 2690 MHz) to flexible use (thus eliminating any remaining provisions for mandatory instructional use in the ITFS portion); (3) define geographic overlay licenses to exhaustively license the ITFS spectrum; (4) proceed with the design and implementation of our proposed restructuring auction

[49] BBA (1997). §309(j)(14)(A)-(C)

[50] Auction 44. *See*, http://wireless.fcc.gov/auctions/44/factsheet.html .

for this band with special provisions as necessary to take into account existing leasing arrangements between ITFS and MMDS licensees; and (5) identify one or more bands in a higher frequency range that could be auctioned simultaneously as potential replacement spectrum for incumbents who may wish to relocate. This latter step, while not required, would help to avoid uncertainty about the cost and availability of replacement spectrum for incumbents who wish to continue operation in another band.

The 2 GHz MSS bands

A slightly different approach would be appropriate for the 2 GHz MSS band because the 8 MSS licensees have not been assigned specific spectrum blocks and because of possible concerns about creating excessive windfalls for licensees in a service exempt from auctions. Under current rules, each 2 GHz MSS licensee has the right to select a 7 MHz block on a first-come-first served basis once it deploys an MSS system. Since the MSS incumbents do not have specific blocks that could be put into a two-sided auction, an alternative approach would be to offer them a transferable voucher in exchange for returning their MSS licenses. Any portion of the voucher could be used toward payment of any winning bid in any Commission auction. The amount of MSS spectrum made available by returning MSS licenses would be reallocated and auctioned for flexible use including MSS. As in our general proposal, the MSS licensees would have the option to provide MSS under the current rules and would eventually be assigned specific spectrum blocks under current rules. But instead of flexibility as the *quid pro quo* for participating in two-sided band-restructuring auction, the *quid pro quo* would be a transferable voucher in exchange for giving up their MSS license.[51]

The 1710-1755 MHz transfer band and 2110 MHz to 2165 MHz bands

We include the 1710 MHz to 1755 MHz transfer band in our initial restructuring proposal, despite having excluded it earlier when discussing participation problems with government incumbents. This spectrum appears highly complementary for pairing reasons with certain bands

[51] This approach would be equivalent to our general proposal if the transferable vouchers were equal to 100% of the average sales price of the returned licenses. Setting the vouchers at a smaller percentage would limit windfalls received by incumbents. This may be appropriate in this case, since it would discourage regulatory arbitrage (parties petitioning the FCC to allocate spectrum for global/international satellite systems, which are exempt from auction, and requesting flexible use after receiving such spectrum through an administrative assignment). A smaller percentage would also raise revenue for the Treasury, to the extent it is sufficient to induce the return of licenses.

in Column H, particularly those in the 2110 MHz to 2165 MHz range and, if so paired, would be a close substitute for other bands in Column H for bidders seeking spectrum for 3G use in particular, and perhaps for other uses.[52] Non-participation by government incumbents in the auction would not be a problem if the band clearing rules allow the spectrum in commercially important areas to be cleared quickly and at a cost that is predictable to bidders prior to the auction.[53] We note that both the 1710 MHz to 1755 MHz band and the 2110 MHz to 2150 MHz bands are under a statutory mandate to be auctioned prior to September 30, 2002.[54] However, neither band is presently scheduled for auction. We propose that their auction be postponed long enough (we estimate two years) so that they can be included in our proposed initial restructuring auction. Including these bands would increase the total available for the initial band-restructuring auction under our proposal to 438 MHz.

An alternative, smaller auction

If a smaller auction is preferred as an initial implementation, then we propose the ITFS/MMDS and 2 GHz MSS bands as our first choice. Both bands have been identified for potential 3G use. Moreover, some have questioned the commercial viability of certain current uses in the bands, so a large increase in private value from band restructuring is possible. This potential should create strong incentives for incumbents to participate. Restructuring these bands using the mechanism we propose would quickly open 260 MHz of very desirable spectrum for market allocation. We believe this would go a long way toward relieving current spectrum shortages for high growth services and potentially add billions of dollars to the U.S. economy. The resulting transfer of spectrum to higher valued uses would benefit incumbents, consumers, and the U.S. Treasury.

6 Additional Issues

6.1 Legal authority

The FCC's legal authority to include incumbents' licenses in its auctions would have to be determined, as a threshold issue. The plain language in the statute limits the use of auctions to

[52] FCC (2001c).

[53] *See*, NTIA (2001) at http://www.ntia.doc.gov/ntiahome/occ/manreimb/index.html.

[54] BBA-97, Section 3007.

"initial licenses".[55] This ensures that the FCC cannot auction licenses at renewal. The statute was not written with two-sided auctions in mind, and new legislative authority clearly and specifically authorizing such auctions would be desirable. However, it may be possible to proceed without new legislation if doing so would not violate the intent of current law, particularly the "initial license" limitation.

Auctions were conceived as an efficient alternative to comparative hearings and lotteries as a means of awarding licenses subject to competing applications. But historically, most FCC licenses have carried strong renewal expectancy as long as licensees substantially comply with rules and the terms of their licenses. Thus, renewals would not normally give rise to the filing of mutually exclusive applications. Taking back and reauctioning licenses at renewal would eliminate this renewal expectancy and diminish complementary investment particularly toward the end of the license term. Limiting auctions to initial licenses avoids this inefficiency.

Concerns about auctioning renewals do not arise in the context of our proposal, which would not involve any modification to licensees' renewal expectancies or to the renewal process. Moreover we have designed our proposal to be fair to incumbents as well as the general public. Incumbents would gain from the increased value of their spectrum as a result of flexibility, and the public would gain from a rapid and efficient restructuring of the spectrum. To ensure these benefits, flexibility would depend only on participation in the auction. Since licensees would also be free to buy back their licenses and keep the proceeds, they could gain the value of flexibility with no direct cost to themselves, other than the cost of participating in the auction. Thus, since our proposal does not envision using auctions for renewals and would be fair to both incumbents and society as a whole, it may be possible to implement the proposal under the Commission's general public interest authority.

If clarifying legislation is not forthcoming regarding the limitation of auction authority to "initial licenses", and the FCC does not wish to take the legal risk associated with conducting two-sided auctions, it may consider two band restructuring options in addition to purely private auctions. One option would involve incumbents offering clearing agreements instead of licenses. To avoid the "initial license" limitation, the FCC may be able to proceed by specifying that

[55] Communications Act of 1934, Section 309(j)(1).

incumbents are not offering their licenses, *per se*, in its auction but rather voluntary agreements to clear the band at some date certain, such as 1 year after the auction concludes. There would still be an issue as to whether the FCC can expand its use of auctions to include such agreements even though it may not be explicitly prohibited.

A second option would be to link the FCC auction of overlay licenses with a simultaneous, privately run auction of incumbents' licenses or clearing agreements. In a linked auction, however, it may be impossible or at least cumbersome to allow package bids that include both the FCC's and incumbents' licenses. If package bidding for encumbered and unencumbered spectrum were not possible, some aggregation efficiency would be lost.

Aside from the issue of whether the FCC has the authority to conduct any two-sided auctions, there is a question of statutory authority to auction spectrum allocated for certain specific purposes. The FCC does not have the authority to auction initial licenses used for public safety radio services, noncommercial educational broadcast stations, and international satellite services.[56] It is possible that the FCC could auction spectrum now set aside for these purposes if it reallocated the spectrum for flexible use. Moreover, there would appear to be no legal bar to incumbents selling such licenses in a secondary market.

As far as spectrum allocated for federal users, NTIA does not have explicit legal authority to use auctions to assign such spectrum, and federal government users do not have authority to sell their spectrum. Legislation would likely be required to allow government incumbents to offer spectrum in a band-restructuring auction conducted by the FCC.

6.2 Incentives to adopt our proposal – winners and losers

While we believe that adopting our proposal will result in a large net gain to the economy, that does not ensure the necessary political support at the FCC, NTIA and Congress to implement it. That support will depend on the distribution of gains and losses as well as the size of the net gain. Our analysis suggests that the proposal will benefit consumers, while firms and the Treasury may gain or lose.

[56] Communications Act of 1934, Section 309(j)(2). Communications Satellite Act of 1962, Section 647. (Provision added by the ORBIT Act (2000).

Consumers gain from lower prices and greater variety of wireless services. New providers of commercial wireless services generally benefit from the increased supply and lower prices of flexible spectrum. An important entry barrier will be substantially lowered.

Incumbents with spectrum restricted to specific uses or users gain from the increased value of their currently licensed spectrum due to flexibility. However, some may be harmed by the loss of future access to free or below-market priced spectrum. Under the broadest implementation of our proposal, federal government, public safety, non-commercial and shared-use licensees would no longer have access to free spectrum. Commercial licensees that are now eligible to bid for restricted spectrum, *e.g.,* broadcasters, would also face more competition for spectrum. But none of the users in these groups presently have unlimited access to spectrum at zero or below-market prices. Under our proposal such users would face no administrative restrictions (other than for antitrust reasons) on the amount of spectrum they could acquire at market prices. The net effect of having more spectrum available, albeit at possibly higher prices, is ambiguous.

Incumbents with currently flexible spectrum may gain or lose. The price of spectrum currently available for high value uses such as PCS, cellular and mobile data will fall as the supply of such spectrum increases. Holders of such spectrum will incur a loss due to the reduced market value of their spectrum assets. They may also lose from increased competition, because of greater access to spectrum by competitors.[57] On the other hand, to the extent that such incumbents are presently constrained in expanding output and delivering high quality service by the high price of flexible spectrum, they may gain.

Wireless equipment manufacturers may gain or lose. Lowering the price of spectrum should increase the demand for wireless devices to the benefit of manufacturers. But certain established firms with a comparative advantage in influencing the administrative allocation process to their strategic advantage may lose. Innovative firms with new uses or technologies not now permitted under restricted allocations may find it easier to gain access to flexibly allocate spectrum through the market than to pursue allocation changes through the rulemaking process. Firms that are developing software defined radios and other frequency agile technologies or technologies that

[57] In a competitive industry, reducing the price of an input can reduce profits by reducing the price of the output by shifting out the supply curve.

conserve spectrum and assist in the control of interference may gain from a flexible allocation policy that gives licensees greater authority and incentives to manage their spectrum efficiently.

Lawyers, engineers and lobbyist with expertise in the current spectrum management process may lose as well. Those with expertise in market processes, such as economists, are likely to gain. Once initiated, a spectrum market should be less costly to maintain than the current administrative allocation process, providing a beneficial net reduction in transaction costs. There will be start-up costs in developing the necessary market infrastructure for efficient spectrum trading and there will be winners and losers resulting from the re-distribution of transaction related income.

The Treasury gains from the increased value of the "white space" spectrum resulting from the simultaneous offering of encumbered spectrum, but loses from the increase in supply of spectrum competing with the spectrum it holds.

Whether the FCC, the NTIA and Congress gain or lose depends largely on how gains and losses are distributed among their constituencies. Congress has the broadest constituency. It must consider the interests of consumers, all commercial and non-commercial spectrum users, manufacturers of spectrum using equipment and the Treasury. The FCC's constituency is consumers, non-federal government spectrum users, and manufacturers of spectrum using equipment. NTIA's constituency is federal spectrum users, primarily the Department of Defense.

Members and staff of the FCC, NTIA and Congress might also consider the effect of replacing administrative allocation of spectrum on their future influence, income and resource demands. For example, on the one hand, the FCC would gain from not having to make difficult, costly and stressful spectrum allocation decisions by administrative process. The agency would be able to concentrate its limited resources on more productive activities. On the other hand, administrative spectrum allocation is a source of power. With fewer benefits to dispense, Commissioners and staff would have less influence both in office and afterwards.

7 Conclusion

Reforming spectrum policy is like reforming planned economies. The form of the transition from central planning to markets matters, as we have seen in Eastern Europe and Russia.

Markets do not create themselves. The central planners can't just not show up for work one day and expect an efficient transition to markets to occur spontaneously.

The current administrative allocation of spectrum has led to shortages and waste. Markets provide a mechanism for moving spectrum to its highest value uses both now and in the future, as technology and consumer preferences change. But removing barriers to flexible use isn't enough to achieve a rapid transition to the market allocation of spectrum for several reasons. It doesn't make spectrum held by FCC (and NTIA) available for flexible use. It doesn't reconfigure existing spectrum rights into tradable, flexible rights. It doesn't solve the coordination problem of ensuring that all interdependent spectrum is up for sale at the same time. And, it doesn't solve the incentive problems that may prevent efficiency-enhancing trades.

We believe that the FCC can play a unique and profound transitional role in addressing these issues. We propose that FCC organize a series of large-scale, two-sided spectrum auctions in which all spectrum incumbents can *voluntarily* offer the spectrum they now control, along with spectrum held by the FCC. For all spectrum so offered, all restrictions unrelated to interference would be removed. Such large-scale band-restructuring auctions would let spectrum users quickly unscramble the inefficient spectrum allocations that have resulted from 80 years of central planning, allowing spectrum to be used in the manner that best serves the public.

Appendix: Spectrum Rights and Interference Control Under a Flexible Licensing Regime

As discussed in the body of this paper, achieving an efficient market allocation of spectrum requires that spectrum be flexibly, exhaustively and exclusively assigned and that interference rights be properly defined. Flexibility allows licensees to move spectrum to higher valued uses; exhaustive licensing of spectrum rights assures that all spectrum assets can be combined efficiently; and exclusivity internalizes the costs and benefits of spectrum use. A proper definition of interference rights between licensees will minimize the total cost of interference, which is the sum of the cost of damage from the interference, interference abatement, and interference coordination.[58] This section compares the way spectrum rights are defined under traditional versus flexible licensing; analyzes the problem of interference management under a flexible regime; suggests technical rules that may facilitate efficient management of interference; and briefly discusses the issue of whether licensees' right of exclusivity should be limited as a way to provide increased access to spectrum for certain kinds of non-interfering uses.

Flexible versus traditional licenses

A flexible license defines spectrum rights in a fundamentally different way than does a traditional service-specific license. In the traditional licensing approach, the physical dimensions of the spectrum assignment are defined on the basis of a specific use, such as broadcasting or point-to-point relay service. Traditional licensees are viewed as service providers not spectrum managers, and only enough spectrum is assigned to provide a pre-determined service with a pre-determined quality and interference.

Defining traditional licenses is an exercise in detailed central planning. Within a known, fixed allocation of spectrum and with information gathered through public consultation on the likely demand for the service and various technology and cost factors, the FCC pre-engineers a system of assignments that attempts to optimize across a number of conflicting objectives: to maximize the number of assignments; to provide sufficient spectrum for each assignment to accommodate the desired service functionality and quality; to keep licensee's system costs to a

[58] Demsetz (1972); Calabresi and Melamed (1972).

reasonable level; and to minimize interference between licensees. The result is an engineered "grid" of assignments that packs licensees together with only the "minimum necessary" amount of spectrum per licensee and with the minimum necessary spacing between licensees (in frequency and space) needed to prevent unacceptable interference. Maintaining the integrity of this highly engineered grid of spectrum assignments requires that each system's technical specifications be tightly controlled and that any system changes be closely scrutinized. Under the traditional assignment, spectrum rights and expectations (both in terms of one's location in the spectrum grid and interference expectations) are precisely defined. The system defines spectrum rights with considerable clarity, but provides little room for licensee flexibility.[59]

In contrast to the service-centric nature of the traditional license, the essential purpose of a flexible license is to define a quantity of spectrum within which a licensee can provide a wide range of services in response to market forces. Flexible spectrum licensees may or may not be the end users or providers of radio services, but may function as managers of physical spectrum analogous to the role of land developers in the real estate market. The regulatory problem of defining spectrum rights in a flexible regime shifts from defining output services to defining the appropriate nature and size of physical spectrum quantities to be assigned initially and setting other rules that may be useful to licensees in managing interference with their neighbors.

The principal dimensions of physical spectrum are frequency, space and time. Assignable quantities of spectrum - we will call them "parcels" - can be defined by subdividing along these three dimensions.[60] The number of different spectrum parcels that can be assigned is the product of the number of subdivisions along each dimension. For example, dividing a range of spectrum into 5 frequency bands, 6 areas and 2 time periods yields 60 distinct spectrum parcels that can be separately assigned. If the time dimension is not subdivided - as it normally is not - the example would yield 30 parcels. It is the exclusive assignment of these parcels of physical spectrum, and

[59] In some services, *e.g.*, private land mobile and point-to-point relay, the selection of assignments is left to private firms or "coordinators" who engineer-in each assignment on a sequential, first-come basis, under detailed technical rules laid out by the FCC. But the resulting array of assignments has the same grid-like quality. A detailed description of the traditional interference coordination process use in the point-to-point microwave service is contained in Williams (1986).

[60] For a more detailed discussion of the problem of dividing physical spectrum rights see De Vany, *et. al.* (1969)

associated technical rules to control interference between licensees, that define the basic spectrum rights of a flexible license.

Under a flexible license, the licensees themselves are permitted to decide what services to provide in response to market forces. In defining flexible licenses, the traditional assignment grid is replaced with a much less structured "band plan," of assignable spectrum parcels. Designing a band plan for flexible licenses requires that the FCC make much less detailed assumptions about future radio technology and demand for services. While some thought about future uses is relevant to decisions about the initial size and configuration of spectrum parcels (*e.g.*, large bands vs. small bands, regional vs. nationwide, paired vs. unpaired bands) a high degree of regulatory precision is not justified since licensees can readily adjust band and area size in the license auction itself and, at a higher cost, in aftermarket trading. The simultaneous auction is specifically designed to facilitate efficient aggregations, and further auction improvements such as package bidding are being developed.

Interference between licensees

Just dividing physical spectrum into parcels and exclusively assigning them does not provide a sufficient definition of spectrum rights under flexible licenses since it does not address the problem of interference between licensees on different parcels. Interference can occur because transmitters do not perfectly contain their emissions within assigned bands and areas and receivers do not perfectly screen out emissions in adjacent bands. One approach to interference would be to establish a strict liability rule whereby no new use would be permitted to cause *any* interference to an existing use without the permission of the injured party. Under such a rule, even the slightest potential for interference would trigger a need for coordination with other licensees. If interference control requires that licensees coordinate their every move at high cost, then much of the benefits of flexibility and exclusivity may be lost. Allowing some level of interference without the permission of affected parties is more likely to produce an efficient outcome which minimizes the total cost of interference (the sum of the costs of damage, abatement and coordination). But defining "acceptable" interference levels is highly subjective and requires *a priori* knowledge about future uses and technologies that is inconsistent with a flexible, market regime. Instead, we suggest setting objective limits on some of the principal factors that cause interference (*e.g.*, transmitter power at boundaries) and allowing licensees to

deploy unilaterally, and control actual interference, within those limits. There would still be a need for coordination but it would be narrowed to circumstances where licensees cannot operate efficiently within the pre-established limits - principally near geographic and frequency borders. Our suggestions for such limits are discussed below.

Limiting transmitter spill-over

The interference caused by a transmitter's emission spill-over into adjoining bands and areas is a classic externality similar to pollution: the actions of the transmitter owner impose a cost on adjoining licensees. Since it is costly for the transmitter owner to reduce spill-overs while the benefits are external, the transmitter owner will tend to spill-over excessively. It is generally understood that markets do not manage externalities efficiently, and that some degree of regulatory intervention may be efficient.[61]

While some regulatory limit on transmitter spill-over is likely to be efficient, determining the optimal limit requires specific information on costs and benefits that is unlikely to be available to the FCC. Therefore, we suggest that regulatory limits on transmitter spill-over be set conservatively at "reasonable" levels that can be met at low cost, with further refinement left to negotiation between licensees. As with most forms of pollution abatement, a modest limit on transmitter spill-over may yield large net benefits because the marginal cost of initial abatement tends to be low and the marginal benefit high. We suggest applying a regulatory limit on transmitter spill-over at both the area and frequency boundaries of flexible spectrum assignments. The values used in the current PCS rules should be appropriate in most instances.[62] We note that continued improvement in transmitter filtering technology may make it efficient to gradually tighten the limit on adjacent band spill-over, reducing the interference externality and making licenses more independent.

Dealing with strong-signal interference

There is another class of interference that can occur between licensees operating in adjacent bands in the same area that is not addressed by limits on transmitter spill-over. It occurs because receivers do not perfectly filter out strong signals in adjacent bands, and it would be a problem

[61] Varian (1992), pp. 432-439.

[62] 47CFR (2001), §24.236 and 24.238, respectively.

even if transmitter spill-over into the receiver's band were reduced to zero.[63] For a receiver with a given filtering capability, the likelihood of this kind of interference increases as the signal from the interfering transmitter becomes stronger relative to the desired signal being received. This can occur under one or a combination of the following conditions: (a) the receiver is trying to receive a very weak signal (characteristic of satellite signals, for example); (b) the interfering transmitter is very powerful (*e.g.*, a million watt broadcast station); (c) there is little frequency separation between the interfering transmitter and the receiver (they are using frequencies immediately across the frequency boundary); or (d) there is little spatial separation between the transmitter and receiver (*e.g.*, a PCS transmitter in one pocket and a GPS receiver in the other).

Stating the conditions that increase the likelihood of strong-signal interference suggests ways to reduce it: (1) increase the capability of receivers to filter out adjacent band transmissions (increases receiver cost); (2) avoid systems that require reception of very weak signals (may render certain technologies and services uneconomic); (3) limit the in-band power of transmitters (increases the cost of covering large areas); (4) maintain a minimum frequency separation between transmitters and receivers in adjoining bands (requires additional coordination between licensees); and (5) increase the distance separation between transmitters and receivers in adjoining bands (additional coordination required). All of these measures increase cost, reduce flexibility and/or require additional coordination between licensees. For reasons discussed below, we believe there is a case for regulating in-band power and in some instances receiver performance, but that the other contributing factors should be left to licensees.

Because increasing in-band power can increase the cost of receiving systems in adjacent bands, an externality is caused and the need for some regulation is evident. However, as was the case with transmitter spill-over, the goal should be to set a reasonable, not optimal, limit and to rely on licensees to reset the limit more optimally through negotiation. The initial limit set by regulation should rule out extreme power levels that have little practical benefit but which, if left unchecked, could lead to excessive interference risk or harmful strategic behavior. A reasonable power limit is one that is high enough to accommodate most anticipated transmitter systems

[63] A strong adjacent band signal can "desensitize" a receiver so that it must operate with stronger desired signals thus increasing the cost to the receiver owner/licensee. A strong adjacent band signal can also mix with other signals in a receiver's circuitry to produce interfering signals called "intermodulation products" that fall directly within the frequency band of the desired signal. Interfering signals that are on the same frequency as the desired signal cannot be removed with conventional filtering techniques without also reducing the desired signal.

while helping to constrain "worse case" interference assumptions on the receiving side. A high degree of precision in setting the limit is not necessary since licensees will have the ability to reset it more optimally through negotiation, albeit also at some cost.

Limiting transmitter in-band power and spill-over into adjacent bands and areas, together with the definition of assigned frequency bands and areas, provides substantial definition to the interference environment in which licensees must design their systems. Given these rules, licensees should be able to make efficient investment decisions regarding receiver interference abatement technology since the costs and benefits of such investment would be internal to licensees. Thus, in general, we do not believe that regulation of receiver interference performance is necessary. However, receiver regulation may be efficient in the following special situations: (1) where the permissible levels of transmitter spill-over and in-band power levels have not been clearly defined for adjacent bands and (2) where the FCC itself is acting, and will continue to act, as the default system designer and interference manager, *e.g.*, in traditionally licensed broadcast bands.

In the first situation, which may be a transitional condition until spectrum has been broadly restructured and exhaustively licensed as proposed in this paper, licensees may under-invest in receiver interference performance in developing new systems on the assumption that adjacent bands will remain unassigned or that they can acquire additional protection for their receivers later through the political process. Once overly susceptible systems have been deployed, changing them can be very costly. Under these conditions, excessive restrictions on transmitters in adjoining spectrum may be necessary. The result could be to encumber a large amount of spectrum well beyond the nominal frequency assignment of the new system without consideration of the opportunity cost. This problem can be addressed either by establishing default interference levels that licensees must accept from adjacent bands even if those bands have not yet been licensed, or by imposing minimum performance standards on receiver interference tolerance. We suggest that both approaches be considered.

The second situation is an artifact of the current process where the FCC itself serves as the default band manager and would need to make the efficient trade-offs in receiver performance vs. cost, including the opportunity cost of the spectrum. In this environment no party (other than the FCC) is in a position to adequately weigh the costs and benefits of better interference

abatement in receivers. Absent a general restructuring of broadcast spectrum for market allocation along the lines developed in this paper, the incentives for efficient receiver design will continue to be inadequate. In that case, regulatory standards may be the efficient second-best solution.

As a general point, we note that improving technology may make it appropriate to tighten limits on transmitter out-of-band emissions and receiver discrimination over time. This would allow licensees generally to reduce coordination and tend to commoditize spectrum, thus increasing the liquidity and efficiency of the spectrum market. This improvement in market efficiency may not be fully appreciated by individual licensees.

Licensees' right to exclude non-interfering uses

While the right to exclude interfering uses facilitates the efficient operation of a spectrum market, it is less clear whether a licensee should have the right to exclude non-interfering uses. New technologies are emerging that may allow additional, valuable uses of exclusively assigned spectrum on a non-interfering basis. One class of non-interfering technology uses emissions that are so low in power as to have no perceptible effect on the primary rights owner (*e.g.*, UWB). A different, higher power technology, sometimes referred to as "cognitive radios" may be able to detect, use and release otherwise unused spectrum on a real-time, opportunistic basis with no effect on the primary rights holder. Either technology could theoretically expand the amount of spectrum available for other users without the cost of negotiations with primary rights holders and without materially degrading the primary licensee's enjoyment of its spectrum. If this is true, there may be merit in allowing such uses on a commons basis as some have proposed.[64]

However, there remains considerable question as to the practical feasibility of non-interfering technology of the higher power opportunistic variety. For example, a path obstruction such as a hill or large building between an opportunistic device and a protected licensee's transmitter could cause the device to detect a false "opportunity" to transmit, resulting in interference to the primary licensee's receiver in a direction that is not obstructed. The feasibility of high power, opportunistic use would depend on finding practical solutions to this and other

[64] *See*, Faulhaber and Farber. (2002)

implementation problems and without imposing significant costs or restrictions on the rights of the primary licensees.

We have the additional concern that high power opportunistic uses, particularly if deployed in great numbers under an open commons approach, might be able to acquire *de facto* "squatter's rights" though the political process (much like poor receivers, discussed above), and thus erode the essential rights of primary licensees without consideration of the opportunity cost. Once opportunistic devices have populated a band, it may be politically difficult for a primary licensees to "evict" them when it needs the spectrum. Primary licensees may effectively be locked in and prevented from changing their technology or usage in ways that either reduce the spectrum available for opportunistic devices or expose the primary licensee to interference from opportunistic devices already in the environment. The possible emergence of squatter's rights for these devices coupled with the lack of price rationing that characterizes a commons approach could result in lower valued, opportunistic uses crowding out higher valued uses of the primary licensee. So while the potential of this technology is promising, a cautious approach to implementation seems appropriate.

An alternative to the commons approach would be to incorporate the rights to use the opportunistic technologies into the flexible overlay licenses that are auctioned in encumbered bands. Overlay licenses that have been issued, *e.g.*, in the PCS bands, presently include the right to opportunistic use of spectrum in the geographic and frequency domains as part of the "white space" around encumbered spectrum. Adding the time dimension would exhaustively license all of the usable "white space" in all dimensions and make additional spectrum immediately available for market allocation by the overlay licensee without the need to clear or otherwise bargain with incumbents. Overlay licensees would have the correct incentives to use these new technologies where they are efficient, and potential squatter's rights problems would have been avoided.

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