Before The
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In The Matter Of	)	
	)	
Service Rules for the 698-746, 747-762 and 777-792 MHz Bands	)	WT Docket No. 06-150
	)	
Implementing a Nationwide, Broadband, Interoperable Public Safety Network in the 700 MHz Band	)	PS Docket No. 06-229
	)	

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I. Introduction

We address a single question posed in the Commission's Second Further Notice of Proposed Rulemaking, which seeks comments regarding the licensing and reauction of the 700 MHz D Block.[1] The Notice identifies several potential sources of revenue to support the cost and build-out of a nationwide, interoperable broadband network for America's first responders, under the scenario in which the D Block is not itself set aside for a first-responder network. One potential source of revenue identified in the Notice is an auction of the TV "white space"—*i.e.*, those portions of TV channels 2-51 that will be unused following the DTV transition. In that context, the Notice asks for an estimate of the value of the white space.[2]

In Comments submitted in 2007 in a separate proceeding, two of us, Jackson and Robyn, argued that the FCC should auction the rights to the white space just as it has auctioned other spectrum rights.[3] Specifically, Jackson and Robyn showed why that approach would benefit consumers far more than would allocation of the TV white space for unlicensed use. They provided a detailed calculation of the quantity of white space that would be available under five different scenarios as defined by alternative interference-protection rules. A key finding was that there would be roughly twice as much white space available under a licensed regime compared to an unlicensed regime, because the latter a) would require more conservative interference-protection rules, and b) could not accommodate interference negotiations ("Coasian bargaining") with broadcasters. Using the most conservative of their three licensed scenarios, Jackson and Robyn also provided a "ballpark" estimate of the auction value of the corresponding white space.

In these Comments, we first update that 2007 estimate of the quantity of white space, by incorporating more recent information on the number and location of DTV stations that will operate after the transition. In addition to the three licensed scenarios used in the 2007 report, we include a fourth licensed scenario that excludes certain channels. (We did not update the unlicensed scenarios, since those results would not inform our calculation of spectrum value).

Second, we refine the 2007 estimate of the value of the white space in three ways. One, as our "market comparable," we use the E Block of the Lower 700 MHz band, which was recently sold in the FCC's Auction 73 and which more closely resembles the white space than does the spectrum used in the 2007 analysis. Two, we calculate the value of the white space on a geographically disaggregated basis in order to make use of market-specific price data on E Block licenses. Three, we take account of "demand elasticity"—*i.e.*, the fact that white space will add to the overall supply of licensed spectrum, leading to a decrease in spectrum value.

In brief, we estimate that an auction of rights to the white space would generate from $9.9 billion to $24.4 billion, depending on the interference-protection rules and the number of channels covered by the auction.

1 *Second Further Notice of Proposed Rule Making*, FCC 08-128, released May 14, 2008.
2 *Ibid.*, ¶ 191.
3 Comments of Charles L. Jackson and Dorothy Robyn in ET Docket 04-186, January 31, 2007. See also Reply Comments of Jackson and Robyn in ET Docket 04-186, March 2, 2007.

II. How Much White Space Will There Be?

Our basic approach to calculating the quantity of white space entails three steps.[4] First, we define white space as those locations—in frequency and geography—where broadcast signals do not need protection. We use the FCC-designated coverage area—the equivalent of a grade B contour for analog TV stations—as the measure of what needs protection, and we estimate that coverage area for each DTV antenna, based on its location, power and height. Our analysis incorporates more than 12,000 antennas, including more than 2,700 full-power DTV stations;[5] some 2,000 non-full-power DTV stations; and more than 7,000 Class A TV stations, TV translators and land mobile systems (see Appendix A).[6]

Second, we calculate the population within the protected service contour of each station. To do that, we sum the population in every census block group within an individual contour. Individual census block groups are about 16 square miles in area and include about 1,300 people. There are more than 200,000 census block groups in the United States.

Third, for each of the 49 channels in the TV band (2-36 and 38-51), we calculate the total U.S. population that is covered by antennas operating on that channel anywhere in the country.[7] Through simple subtraction, we then calculate the population that is not covered by that channel (total population in a given geographic area minus the number of people covered by a particular channel in that geographic area equals the number of people not covered by that channel). That non-covered population represents the population in the TV channel's white space. For example, let's say that 50 percent of the total U.S. population is not covered by channel 2; then, on average, we can regard half of channel 2 as white space on a national basis.

Scenarios

The quantity of available white space will vary depending on the interference-protection rules set by the FCC; the more conservative the rules, the less white space there will be. In our 2007 analysis, we defined three licensed scenarios, corresponding to alternative sets of interference-protection rules. We use those same scenarios (X, Y and Z) for our updated analysis here. We also include a fourth scenario (Q), which—in addition to incorporating our most conservative set of interference-protection rules—excludes certain channels in order to provide additional protection for land mobile systems, which operate in channels 14-20, and medical telemetry applications, which (along with radio astronomy) operate in channel 37 and may be seen to require adjacent channel protection.

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4 For more detail on our methodology, see Jackson and Robyn, *op. cit.*, Appendix A, pp. 3-9.

5 Note that the FCC's table of DTV assignments contains only 1,815 entries; however, our figure (2,700) includes Canadian and Mexican stations, as well as some construction permits and applications, none of which appear in the FCC table.

6 We calculate the protected coverage area for low power TV stations and translators just as we do for DTV stations. For land mobile systems, we use an exclusion zone around the center of each city in which such systems are permitted to operate in the TV band.

7 Throughout our analysis, we exclude channel 37. Channel 37 is set aside for radio astronomy and medical telemetry, and it is not considered part of the TV band.

- Scenario X:
  - Includes all DTV and Class A stations and land mobile systems
  - Co-channel protection only; no adjacent channel protection

- Scenario Y: Same as Scenario X but provides for adjacent channel protection[8]

- Scenario Z: Same as Scenario Y but also includes TV translators

- Scenario Q: Same as Scenario Z, but with certain channels (14-20, 36 and 38) excluded

Analysis

For each scenario, we first calculated the amount of white space available on individual channels and then aggregated across all 49 channels (or a subset thereof, for Scenario Q).

Next we calculated a cumulative distribution of white space for each scenario. A cumulative distribution shows the minimum amount of white space (measured in 6 MHz increments) that is available to any given fraction of the population. It is perhaps the single most important quantity measure, because it speaks to the commercial feasibility of nationwide service: a national entrant would probably need to have at least 6 MHz of white space in enough geographic locations to reach most (say, 90 percent) of the population in order to offer such service.

Finally, we calculated the amount of white space available at a regional level for each scenario. Specifically, we used the 52 Major Trading Areas, or MTAs, each of which contains a major metropolitan area and surrounding rural areas. For each MTA, we calculated the *average* amount of white space (averaged across census block groups). In addition, and to provide a more meaningful measure of capacity, we calculated the *minimum* amount of white space available to each MTA as measured in 6 MHz increments. We define "minimum" to mean the smallest amount of white space available to *any* census block group within the MTA. This is a conservative approach, because it takes the lowest common denominator among census block groups, and an MTA contains thousands of census block groups.[9]

Results

Table B-1 in Appendix B provides a summary of our key results for all four scenarios. In addition, Appendix B includes charts for each scenario showing a) the cumulative distribution of

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8 For those scenarios that provide adjacent channel protection (Scenarios Y, Z and Q), we followed the basic approach described above, but we treated each DTV facility as if it operated at three channels—its own channel and the channels directly below and above.

9 Let's say that, in a particular MTA, most census block groups have access to 24 (or more) MHz of white space, but one census block group has access to only 6 MHz of white space. We would report that the minimum amount of white space available to that MTA is 6 MHz.

white space nationwide, and b) the minimum amount of white space by MTA. Our key findings are:

- There is a large amount of white space available under all three of our updated scenarios (X, Y and Z). Our updated analysis shows a relatively small drop in the total amount of white space available, compared to our 2007 analysis.
- Scenario X, which does not provide for adjacent channel protection, has significantly more white space than Scenarios Y and Z, which do. Under Scenario X, 100 percent of the U.S. population has access to at least 60 MHz of white space.
- Adjacent channel protection reduces the total amount of white space available by about half. However, even under Scenarios Y and Z, which provide such protection, there is a critical mass of white space available nearly everywhere. Most significant, 95 percent of the population has access to at least 12 MHz of white space, and 90 percent has access to at least 24 MHz of white space. And only one MTA (New York) does not have access to at least 6 MHz of white space under Scenarios Y and Z.[10]
- Scenario Q, our new scenario, which excludes channels 14-20, 36 and 38, has roughly one quarter less total white space than Scenarios Y and Z. Even so, 95 percent of the population has access to at least 12 MHz of white space, and 90 percent has access to at least 18 MHz of white space.

III. How Much is the White Space Worth?

The white space is attractive spectrum because it could be used to provide wireless broadband service, both fixed and mobile. The UHF white space (500 MHz to 700 MHz) is particularly well suited for providing wireless services over relatively long distances; because of the nature of the spectrum, a licensee can deploy a new network or expand an existing network using far fewer cell sites than would be required at higher frequencies.[11]

For purposes of valuing the white space, the most comparable spectrum is the E Block from the Lower 700 MHz Band that was recently sold in the FCC's Auction 73. The Lower 700 MHz E Block consists of one 6 MHz block (television channel 56) divided into 176 Economic Area (EA) licenses. The band sold for $1.3 billion—or a nationwide average price of $0.74 per MHz-Pop.

The E Block fairly closely resembles the white space spectrum for several reasons. First, like the white space, it is unpaired spectrum. Moreover, because it is unpaired, the service rules that specify how the E Block can be used are probably similar to those that would govern the white

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10 Note that this result does not mean that no one in New York has access to 6 MHz of white space. Rather, it means that there is at least one census block group that does not have access to 6 MHz of white space. See the discussion above as to how we measure the "minimum" white space available to an MTA.

11 Spectrum and wireless base stations are substitutes: a capacity-limited wireless system can expand by using more spectrum at existing cell sites or by building additional cell sites.

space.[12] Second, the Lower 700 MHz E Block is a single 6 MHz block of (unpaired) spectrum. As a practical matter, systems operating in the white space will probably be engineered to use it in 6 MHz units. Finally, the value of the E-block licenses in a number of major urban markets reflects licensees' plan to use the spectrum to provide a down-link only service.[13] This application makes economic sense for the white space as well, especially in urban areas, where the challenge of protecting TV broadcast signals from potential interference is more easily met with a down-link only (as opposed to a two-way) service.

To estimate the value of the white space, we essentially take the price of each individual E Block license (expressed in cents per MHz-Pop) and apply it to the quantity of white space available in the corresponding Economic Area. Note that this is a significant improvement over the standard approach to spectrum valuation, which in this case would be to apply the average price paid for E Block licenses across the United States ($0.74 per MHz-Pop) to the overall quantity of white space. By using a geographically disaggregated approach, we can take advantage of the market-specific price data on E Block licenses that we have from Auction 73. This approach produces the unadjusted prices for white space as shown in Table 1 below. The average unadjusted price of white space ranges from $0.55 per MHz-Pop for Scenario Y to $0.64 per MHz-Pop for Scenario X.

Table 1
White Space Valuations Using Unadjusted EA-Specific E-Block Auction Prices

Scenario	Scenario X	Scenario Y	Scenario Z	Scenario Q
Average Price (no elasticity adjustment)	$0.64	$0.55	$0.56	$0.56

To further refine our estimate of the value of white space, we adjust the figures shown in Table 1 downward to take account of "demand elasticity." To elaborate, the results of the E Block auction likely overstate the amount of revenue that the white space would generate at auction. This is because the white space will add to the overall supply of licensed spectrum, leading to a decrease in the price of spectrum. Here, as in the step described above, we do the calculations on a market-by-market basis to take into account the variation in the value of spectrum by location. See Appendix C for a technical explanation of our elasticity adjustment.

12 The power limits allowed in the E Block are relatively high, and it is unlikely that a white space operator could operate at those same levels in urban areas and still provide adequate interference protection to broadcast reception. In that one respect, the E Block prices may overstate the value of the white space. On the other hand, a white space licensee may be able to aggregate several white space channels in the same location, thus gaining scale benefits not available to an E Block licensee. In terms of valuation, the two factors would tend to offset one another (if anything, they would favor the white space).

13 QUALCOMM, a major winner of E-block licenses in Auction 73, has announced that it intends to operate a down-link only service in that spectrum. See the QUALCOMM press release of April 3, 2008, "Qualcomm Wins Licenses to Double Its Spectrum in 28 Key East and West Coast Markets to Expand Award-Winning FLO TV Service, New 700 MHz Licenses Will Broaden Content and Service Offering To More Than 68 Million Potential Consumers," available at http://www.qualcomm.com/press/releases/2008/080403_700MHz_Auction.html. The authors' knowledge of QUALCOMM's plans for the E Block is based solely on public information.

Table 2 shows the average price of white space, appropriately adjusted, across all 176 EAs for each of our four scenarios. The average price of white space ranges from $0.48 per MHz-Pop for Scenarios X and Y to $0.50 per MHz-Pop for Scenario Q. Table 2 also shows the corresponding expected auction receipts, which range from $9.9 billion (Scenario Q) to $24.4 billion (Scenario X).

Table 2
White Space Valuations Using Adjusted EA-Specific E-Block Auction Prices

Scenario	Scenario X	Scenario Y	Scenario Z	Scenario Q
Value of White Space (USD billions)	$24.42	$12.35	$11.94	$9.91
Average Price (elasticity adjustment)	$0.48	$0.48	$0.49	$0.50

Appendix A
Composition of Facilities Included in White Space Calculation

Composition of Facilities Included in White Space Calculation

Facility Types	U.S.	Canada	Mexico	Total
DTV Stations				
Digital TV	1,744	838	150	**2,732**
Digital Low Power TV	2,036			**2,036**
DTV Channel Substitution	174	4		**178**
Digital Class A TV	22			**22**
New DTV Allotment	31			**31**
DTV Channel Change	42			**42**
Digital Special Temporary Authority	11			**11**
Others				
TV Translator or LPTV station	6,613	124	25	**6,762**
Class A TV	503			**503**
Land Mobile	22			**22**
Grand Total	**11,198**	**966**	**175**	**12,339**

Sources:
We used FCC’s TV Query data and list of DTV facilities, as reported in the March 2008 decision (FCC-08-72A1), for everything except Land Mobile. For Land Mobile we used 47 CFR 90.305(a).
Note:
We protected Land Mobile operations on channel 19 around Long Island.

Appendix B
Quantity of White Space Available: Scenario Results

Table B-1

Estimated Amount of White Space by Scenario - Summary Results

	Included Facilities	Co-Channel Protection	Adjacent-Channel Protection	Total MHz-Pops (Billions)	Percent of MHz-Pops in White Space	White Space Bandwidth Covering 95%+ of Total Population	Average White Space Bandwidth Available Nationwide
Scenario X	All US, Canadian, and Mexican regular and Class A stations and land systems in the UHF TV spectrum.	FCC Radius	None	50.8	61%	90	178
Scenario Y	All US, Canadian, and Mexican regular and Class A stations and land systems in the UHF TV spectrum.	FCC Radius	FCC Radius	25.7	31%	12	90
Scenario Z	All US, Canadian, and Mexican regular and Class A stations, land systems in the UHF TV spectrum, and all TV translators.	FCC Radius	FCC Radius	24.6	29%	12	86
Scenario Q	Same as Scenario Z, but excludes channels 14-20, 36 and 38	FCC Radius	FCC Radius	19.8	29%	12	70

Figure B-1
Scenario X - Percent of Population With a Given Amount of White Space

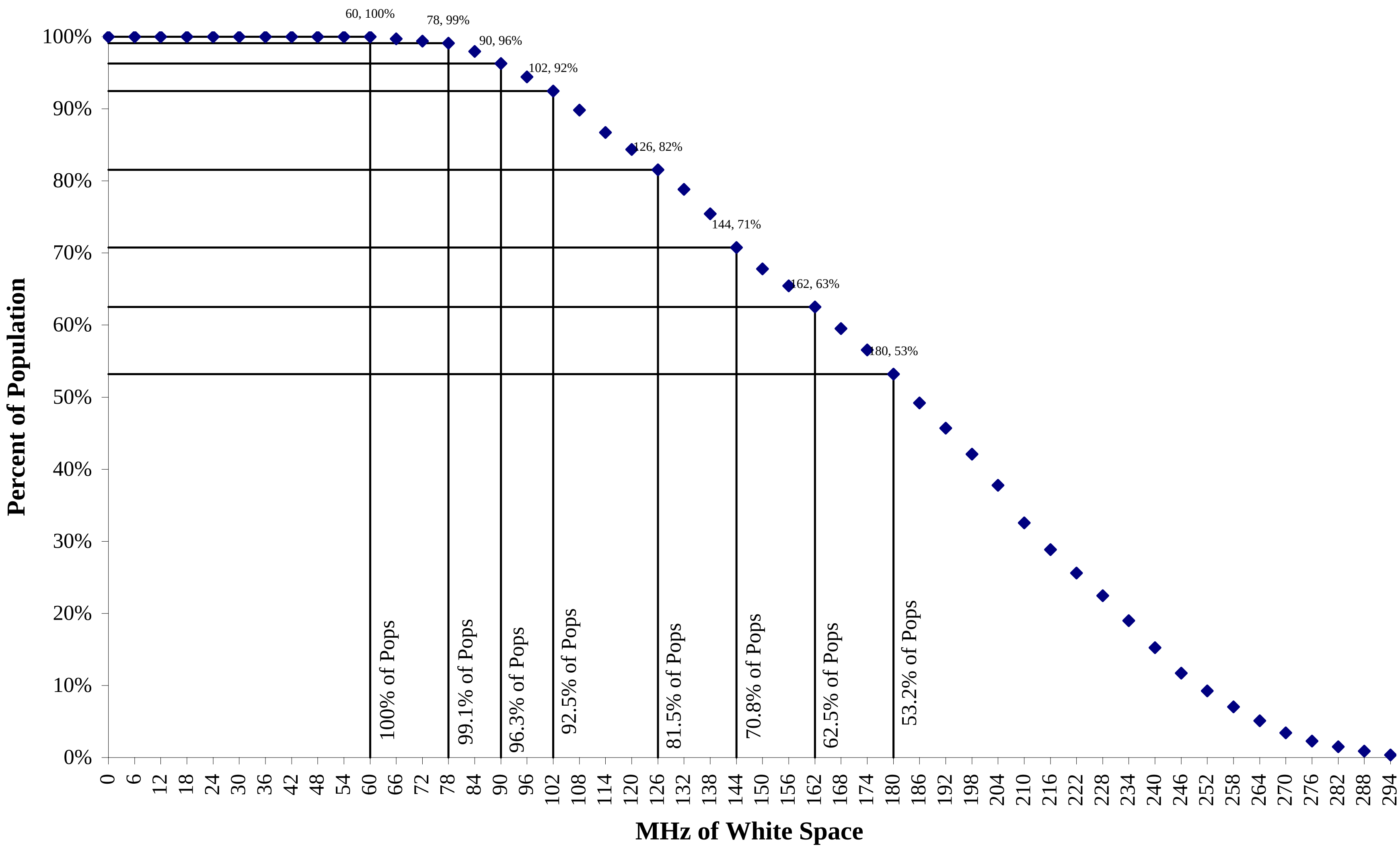


Figure B-2
Scenario X - Minimum Bandwidth of White Space by MTA

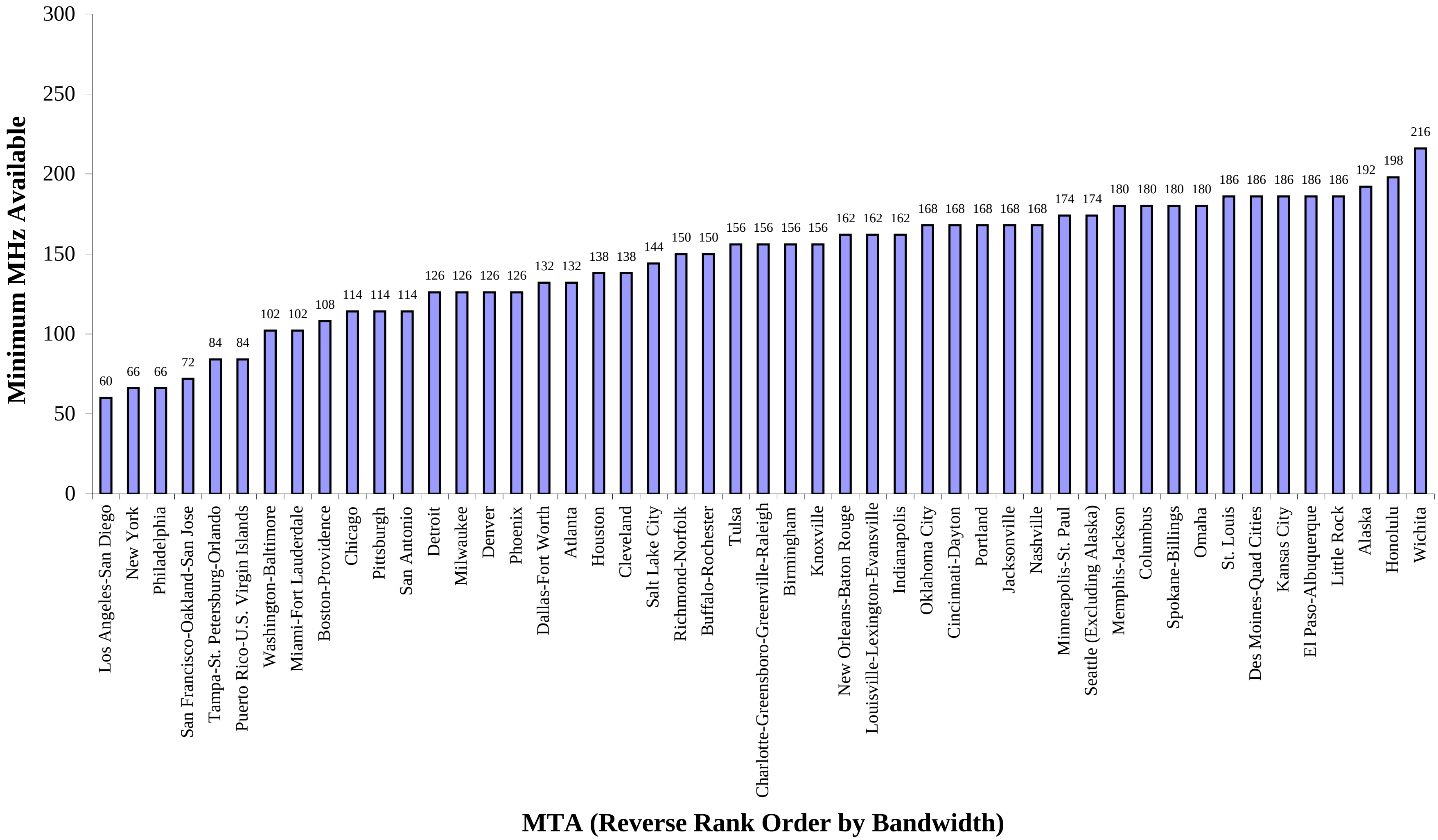


Figure B-3
Scenario Y - Percent of Population With a Given Amount of White Space

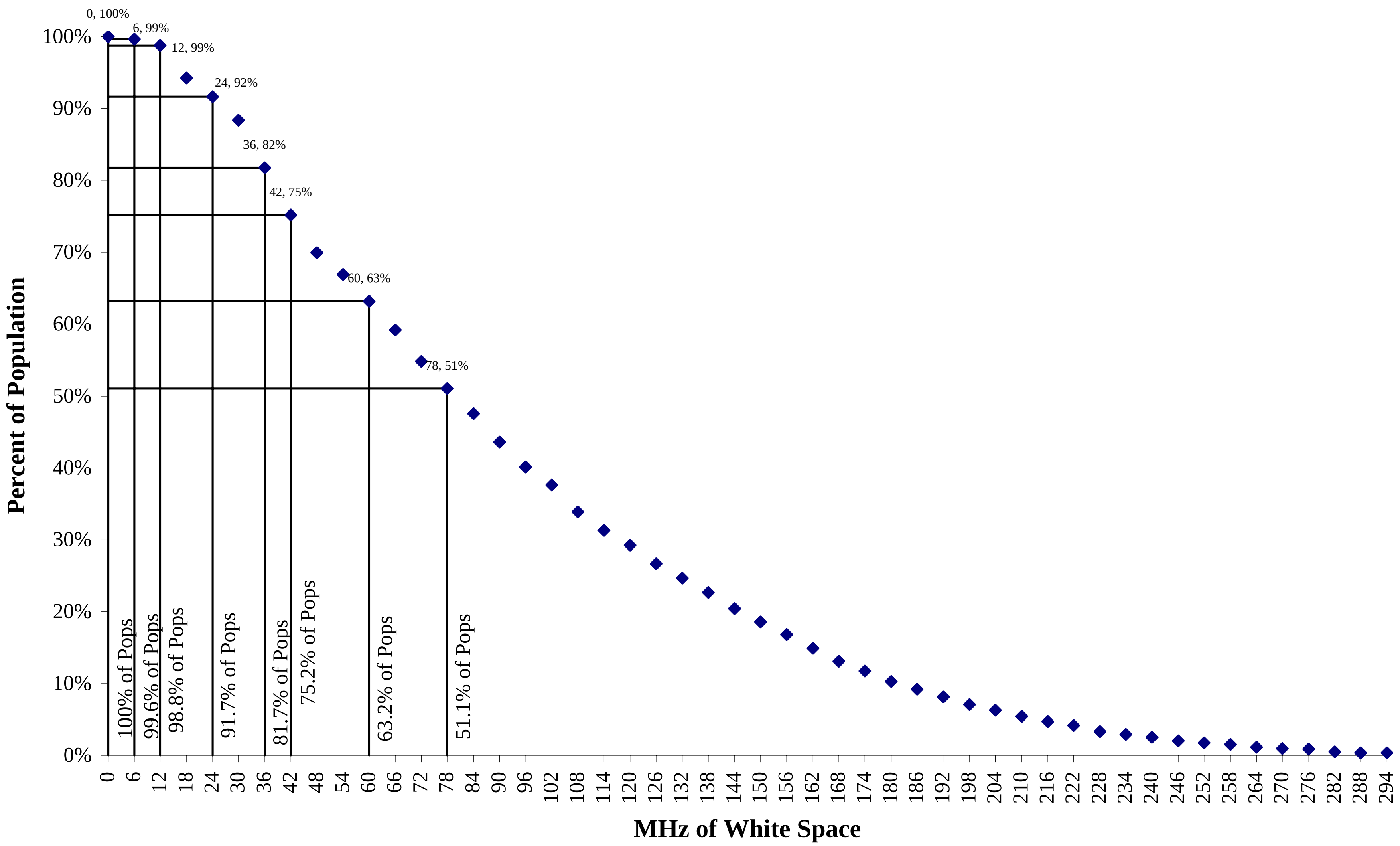


Figure B-4
Scenario Y - Minimum Bandwidth of White Space by MTA

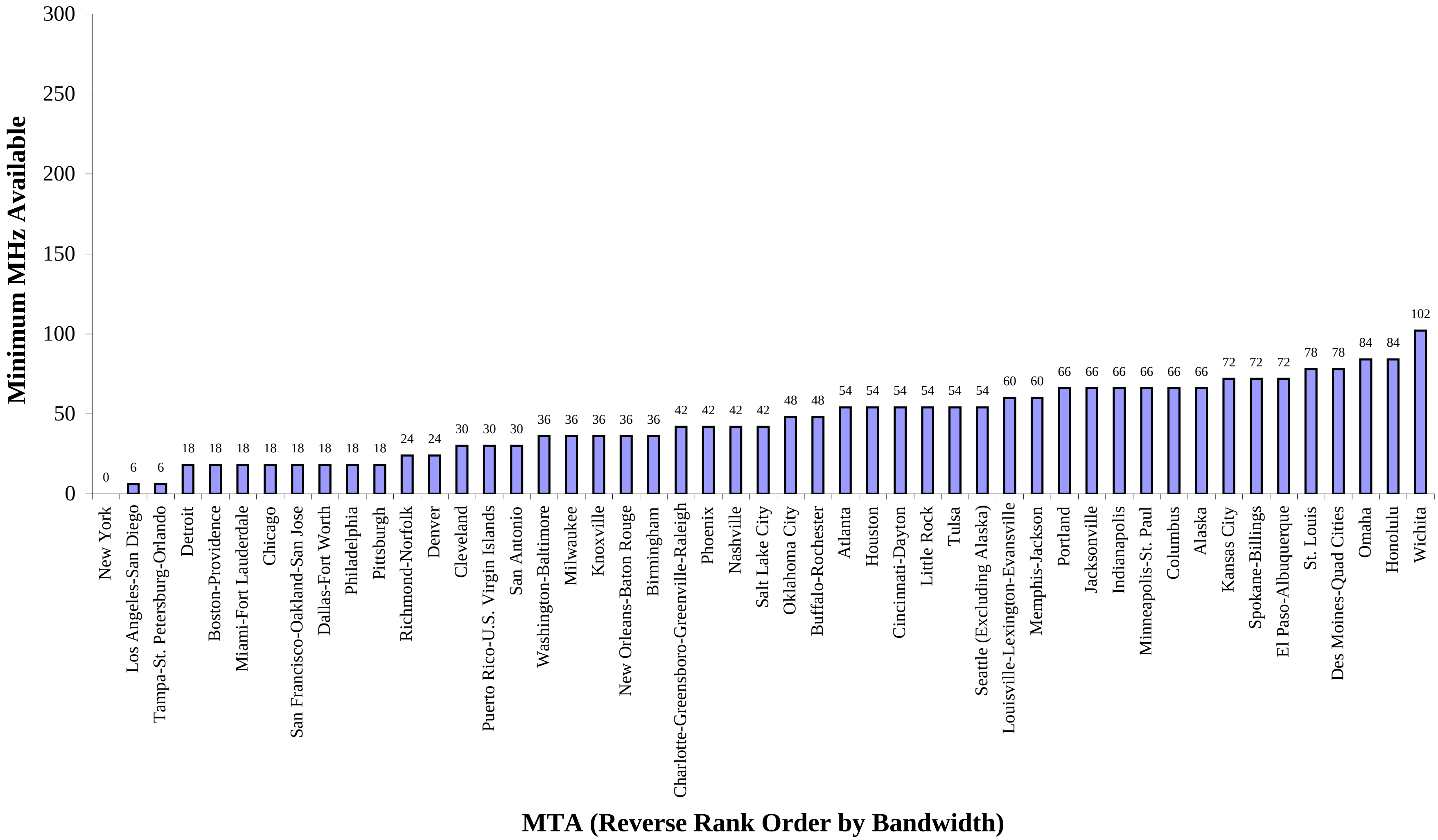


Figure B-5
Scenario Z - Percent of Population With a Given Amount of White Space

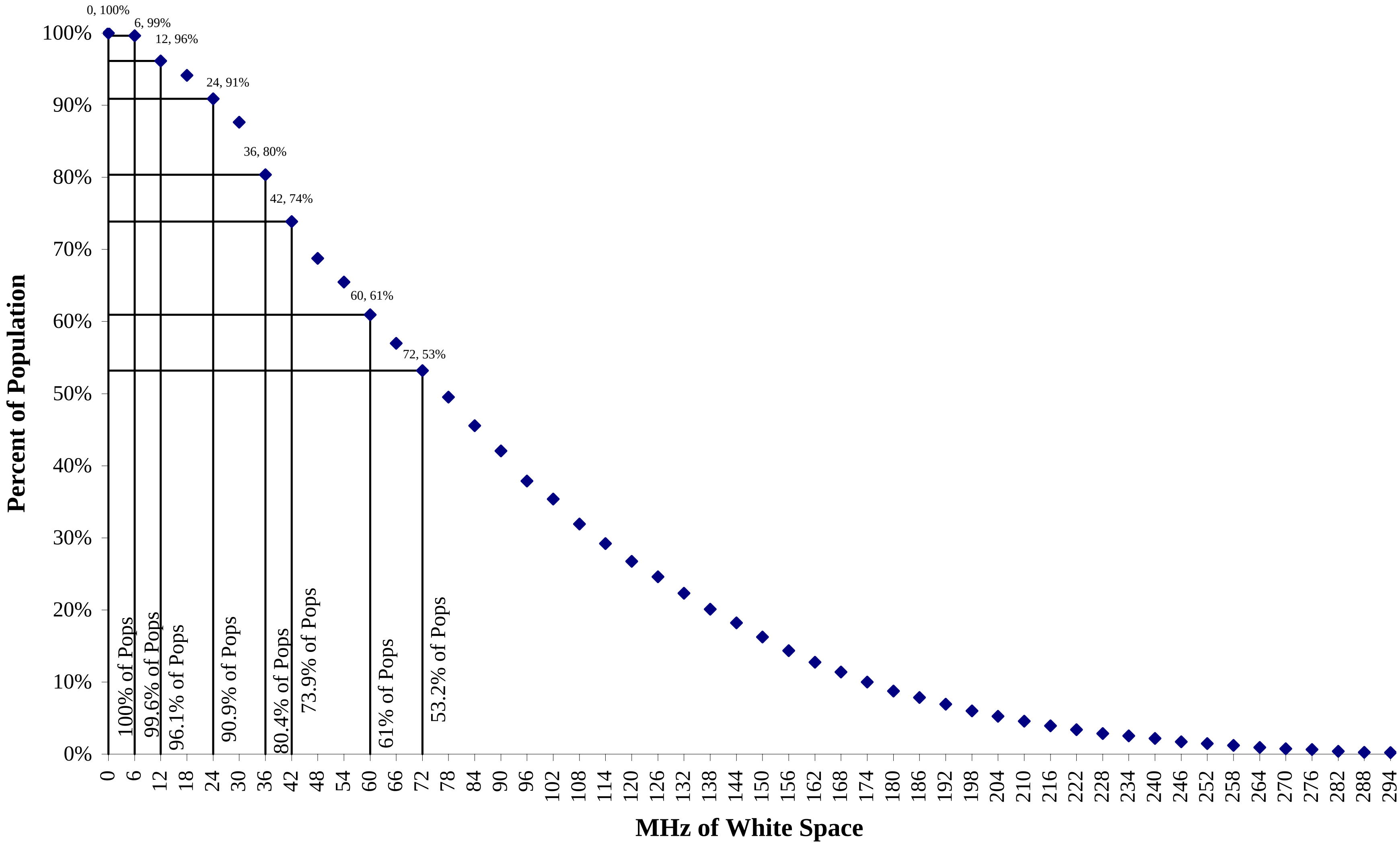


Figure B-6
Scenario Z - Minimum Bandwidth of White Space by MTA

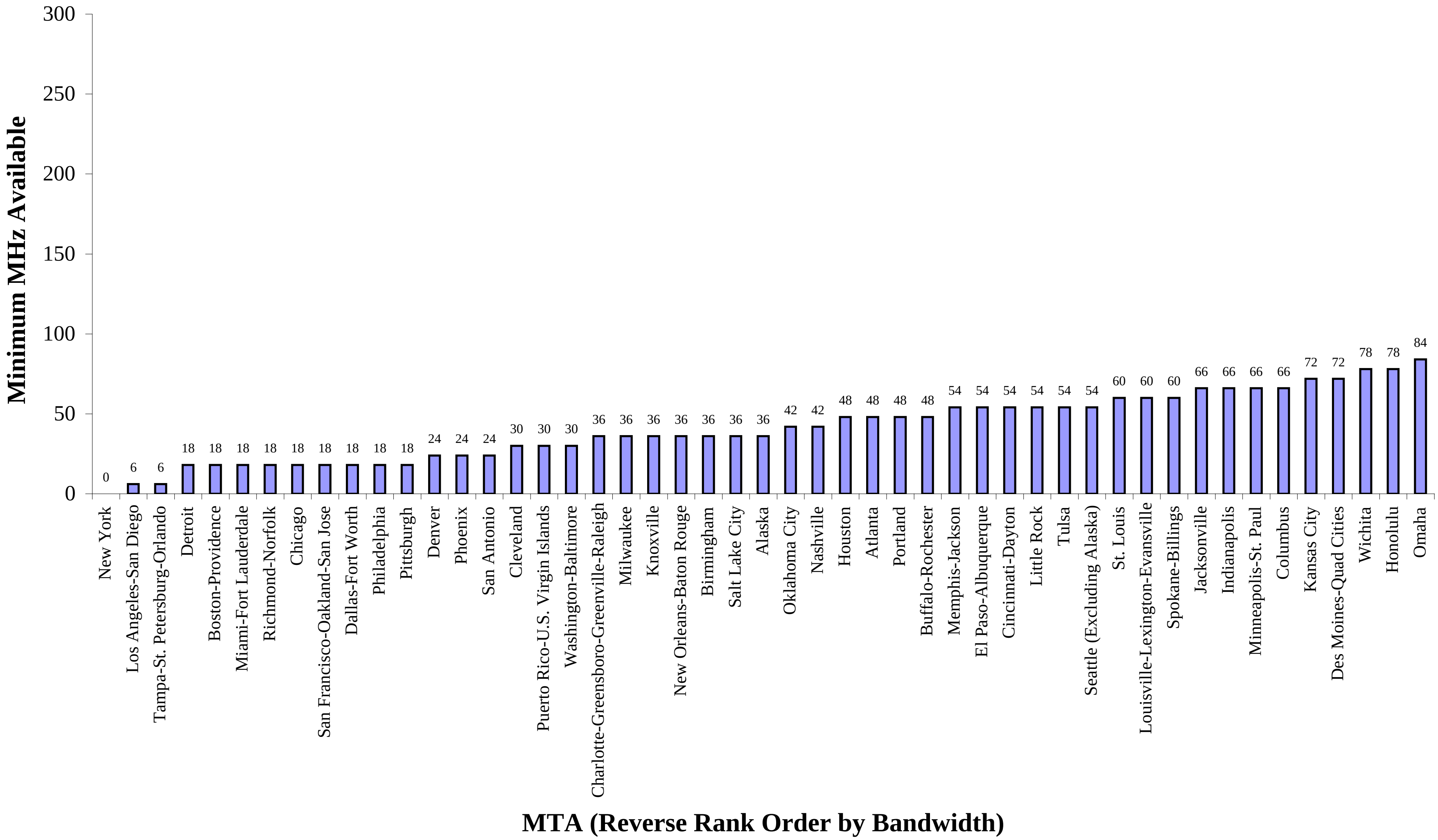


Figure B-7
Scenario Q - Percent of Population With a Given Amount of White Space

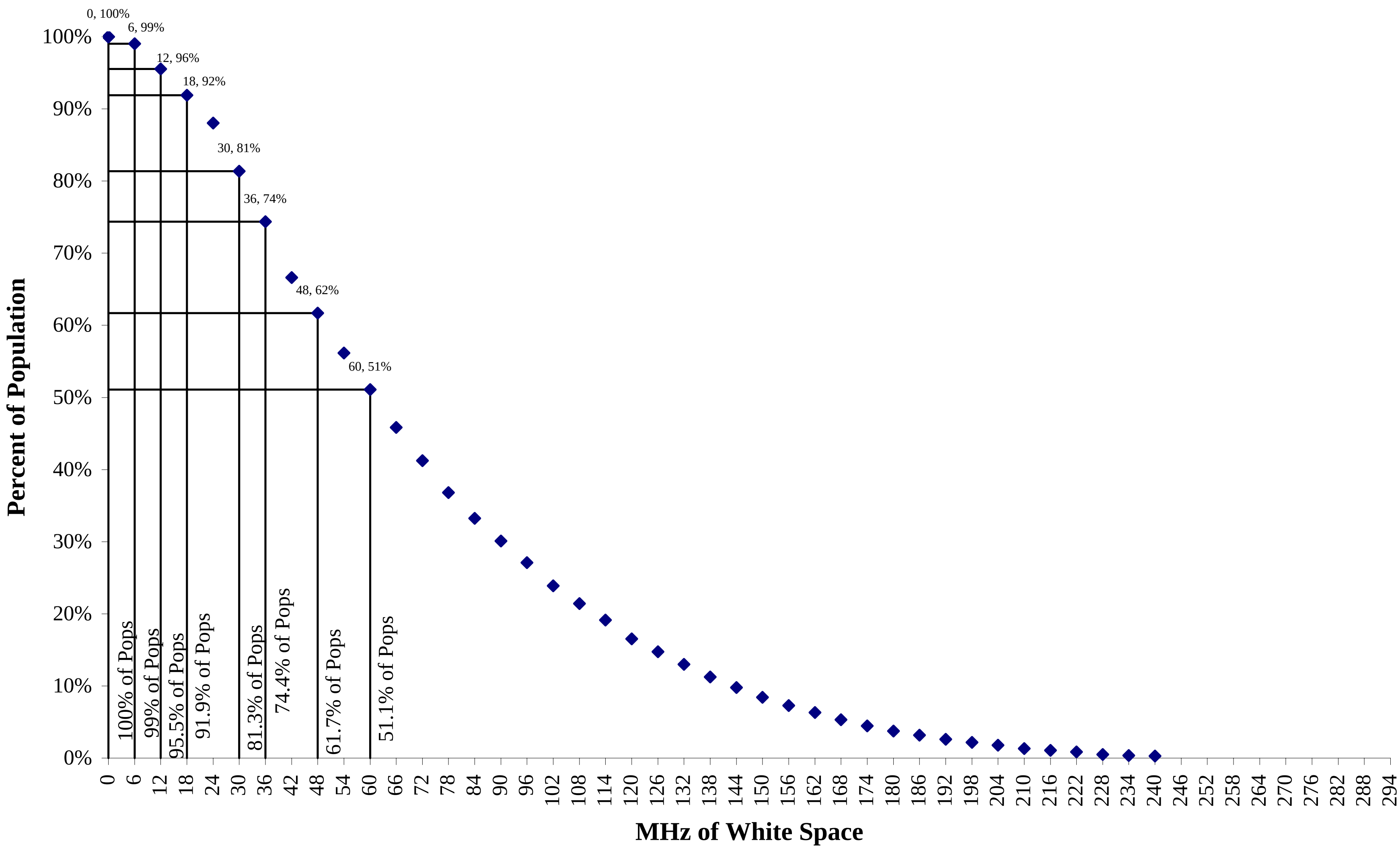
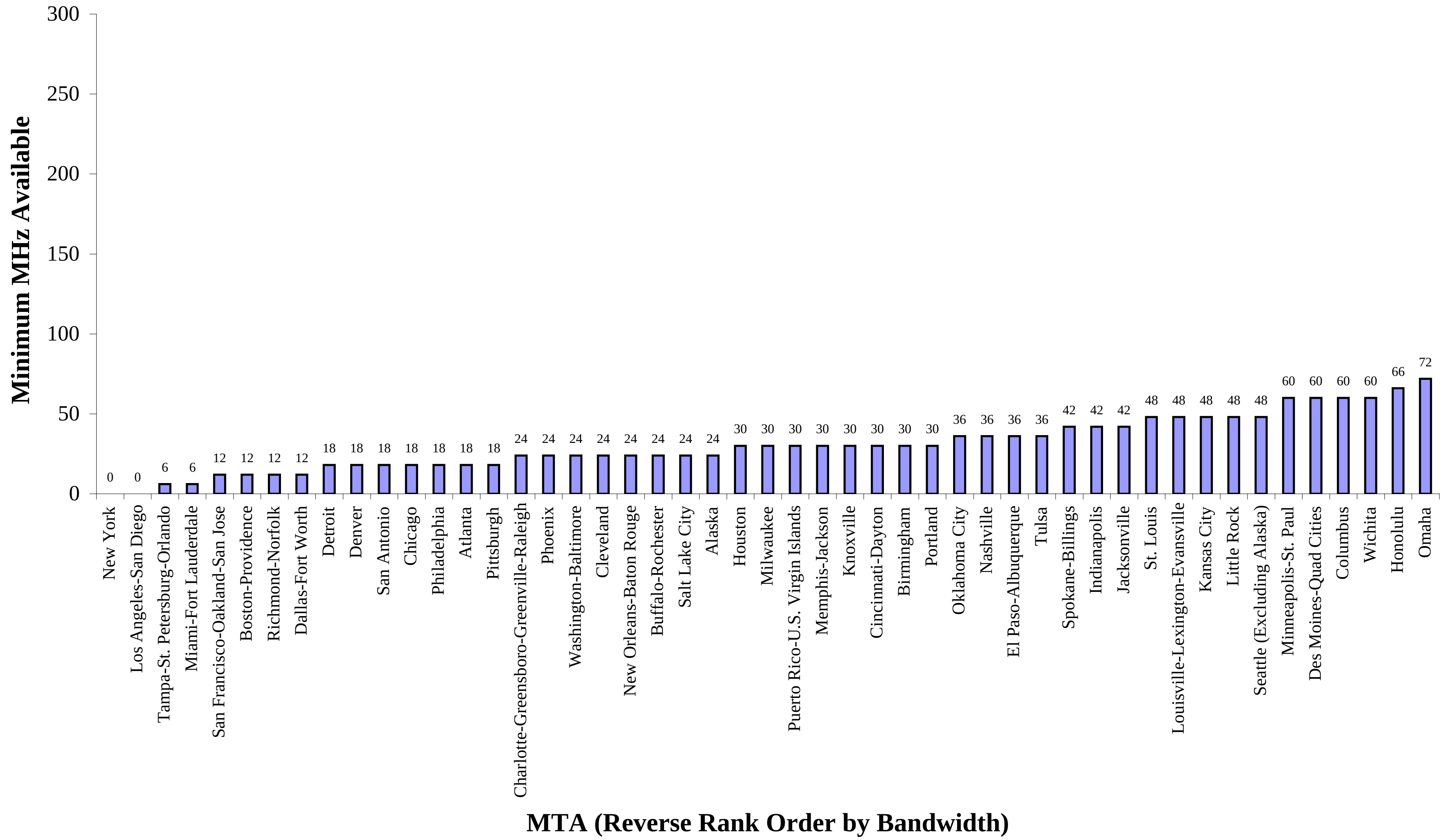


Figure B-8
Scenario Q - Minimum Bandwidth of White Space by MTA



APPENDIX C
Elasticity Adjustment

The Lower 700 MHz E Block consists of one 6 MHz block (television channel 56) divided into 176 Economic Area (EA) licenses. The band sold for $1.3 billion or $0.74 per MHz-Pop. However, the results of the E Block auction likely overstate the amount of revenue that white space would generate at auction. This is because white space will add to the overall supply of licensed spectrum, leading to a decrease in its price. Economists use measures of elasticity of demand to calculate how much an increase in the quantity of a particular good or service will reduce its price.[14]

To calculate the appropriate downward adjustment in price, we utilize the following formula for the elasticity of demand:

$$\eta = \frac{\frac{\Delta Q_i}{Q_i}}{\frac{\Delta P_i}{P_i}} \text{ or } \Delta P_i = \frac{P_i * \Delta Q_i}{Q_i * \eta}$$, where *i* = 1 to 176 for each EA license area.

To calibrate this estimate, we make the following calculations:

- First, we calculate the amount of licensed spectrum available prior to the white space being licensed, Q_i. To do this, we begin with the base of liberally licensed spectrum. See Table C-1 below. The base of 541 MHz is multiplied by the population of each EA to get that EA's base quantity of MHz-Pops.
- Next, we calculate ΔQ as the amount of white space available for each of the 176 EAs under the four scenarios we analyze. The amount of white space is measured as the MHz-Pops available in each EA.
- We then calculate P_i, the price per MHz-Pop for licensed spectrum sold in each EA in the Lower 700 MHz E Band in the 700 MHz auction.
- Finally, we use an estimate of the elasticity of demand, η, for spectrum of -1.2.[15]

With this information and the formula for the change in price we can calculate the EA-specific price ($P_i + \Delta P_i$) for which licensed white space would be expected to sell.

14 The elasticity of demand is measured for any change in a market as the ratio of the percentage change in quantity to the percentage change in price. An elasticity of -1 implies that, on percentage terms, price changes as much as quantity. When demand is elastic—that is, when price changes relatively little in response to a change in quantity—this measure is less than -1 (or greater than one in absolute value). Conversely, large price changes associated with small quantity changes are referred to as inelastic demand.

15 This estimate is taken from Coleman Bazelon, "Analysis of an Accelerated Digital Television Transition," Sponsored by Intel Corporation, 2005. This estimate characterizes demand as slightly elastic. The results do not vary significantly if demand has unitary elasticity. Given the many competing demands for this spectrum, it is unlikely that the demand for white space spectrum is inelastic (elasticity of demand between 0 and -1).

Table C-1
Base Of Liberally Licensed Radio Spectrum

Band Name	Location	MHz	Available
PCS	1.9 GHz	120 MHz	Now
Cellular	800 MHz	50 MHz	Now
SMR	800 MHz / 900 MHz	14 MHz + 5 MHz	Now / Within a few years
Nextel 1.9 GHz	1.9 GHz	10 MHz	Now / Very soon
BRS/EBS-low[1]	2.5 GHz	132 MHz	Within a few years
BRS/EBS-high[2]	2.5 GHz	42 MHz	Within a few years
AWS	1.7 GHz / 2.1 GHz	90 MHz	Now
700 MHz	700 Mhz	78 MHz	2007
Total MHz		*541*	

Sources and Notes:

[1] Includes low-powered licenses only.

[2] Includes high-powered licenses only.