2.7-5 Polarization

Existing microwave links typically use polarized antennas to increase the efficiency of microwave frequency reuse. The antennas are either vertically or horizontally polarized (few links use both), and are almost evenly distributed. In the 1850 - 1990 MHz band there are 4510 horizontally polarized transmitters and there are 4847 vertically polarized transmitters. The difference in the antenna gain between signals using the same polarization and signals using the opposite polarization is called the cross polarization discrimination. Figure 2.7-5.1 shows the difference between the co-polarized gain and the cross-polarized gain for the A24501 antenna and figure 2.7-5.2 shows the same information for the P24100 antenna.

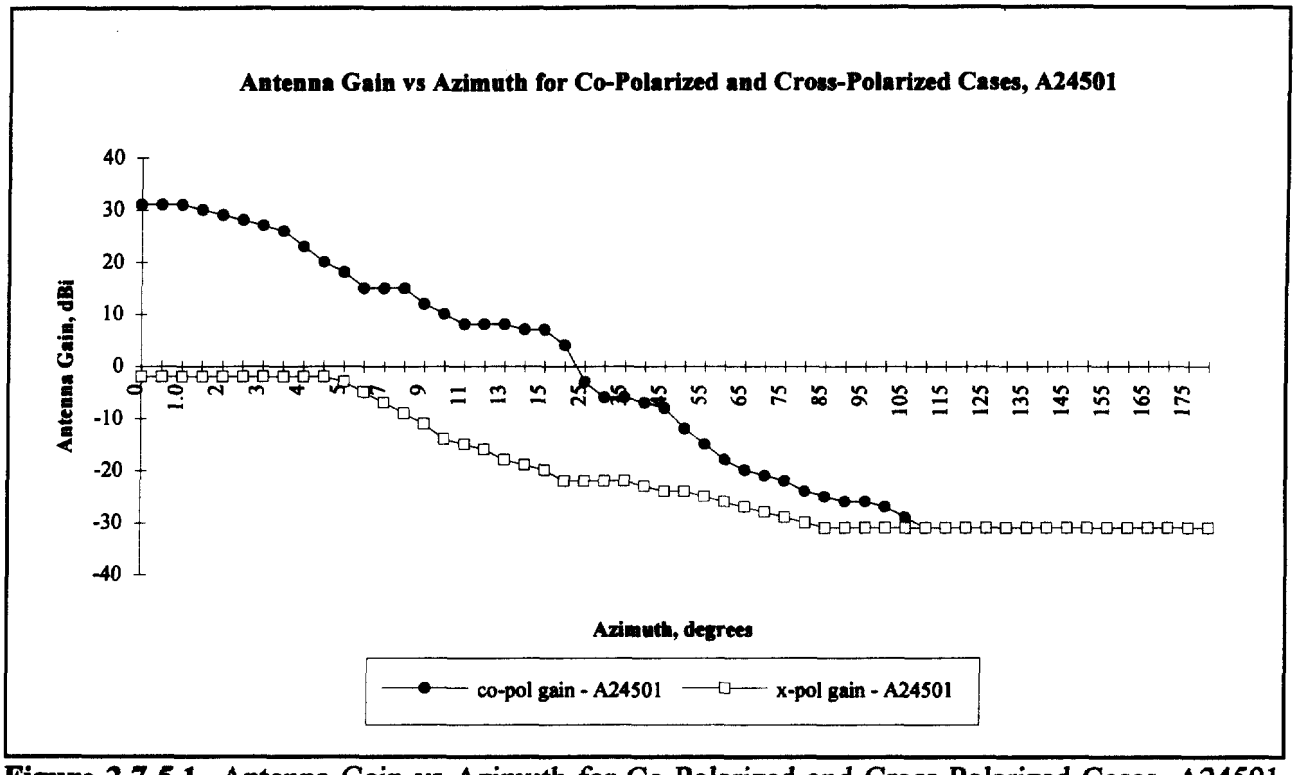


Figure 2.7-5.1 Antenna Gain vs Azimuth for Co-Polarized and Cross-Polarized Cases, A24501

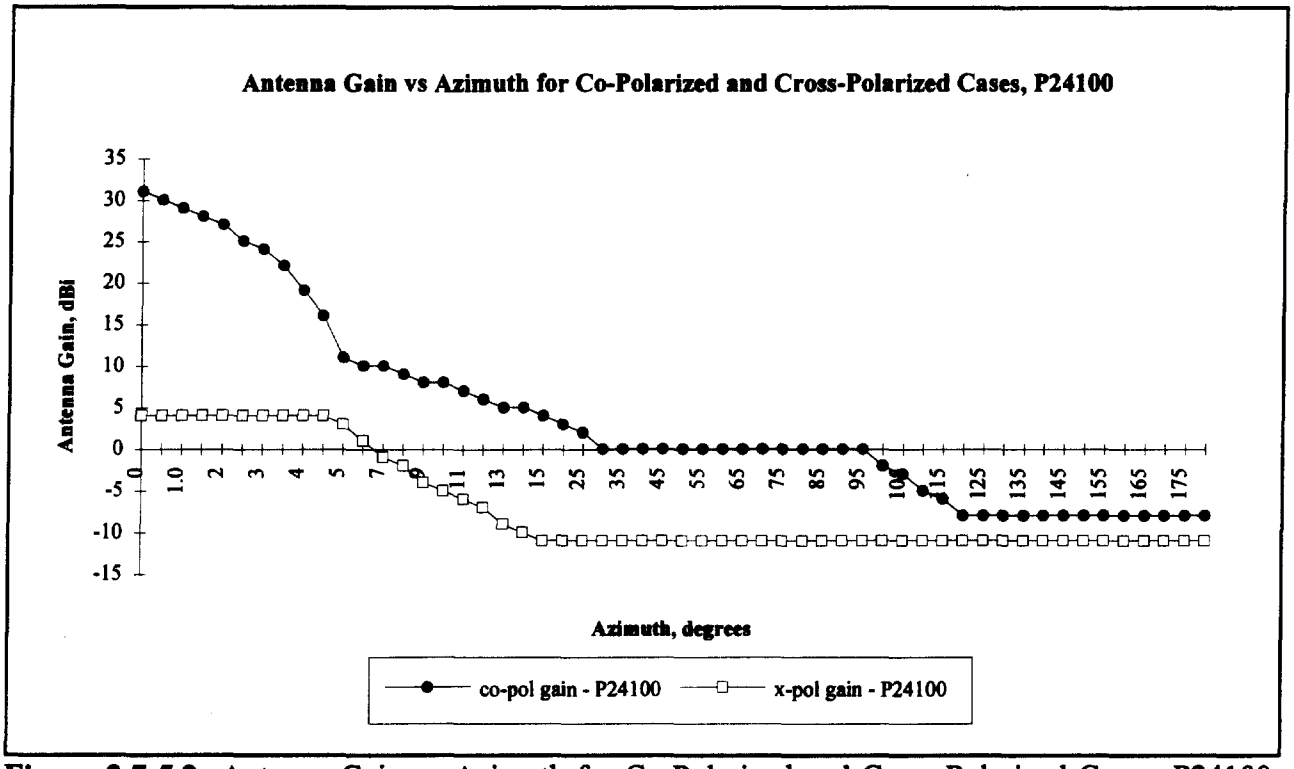


Figure 2.7-5.2 Antenna Gain vs Azimuth for Co-Polarized and Cross-Polarized Cases, P24100

The antennas shown can have 27 - 33 dB difference in gain depending on which polarization case is used. Point-to-point communication systems can take advantage of the cross-polarization discrimination because their systems are designed to minimize the number of obstacles in the path, which could affect the polarity of the transmitted wave. Mobile communication systems can not maintain distinct polarizations because of the number of obstacles and reflectors in the mobile environment. This study assumes a co-polarized interference, a worst case assumption, particularly at very small angles.

3.0 Technical Approach and Results

This section presents an overview of how the analysis is performed and what the specific results are for this study. The first section describes the procedures used to determine the number of microwave links to relocate to meet the spectrum availability requirement of 25 %. The sections that follow that discussion present the output from running the Spectrum Sharing Model for various spectrum allocations.

3.1 Parameter Selection

The Comsearch Spectrum Sharing Tool requires a number of technical parameters to be selected before running an analysis. This section presents the major screens the user navigates to perform an analysis.

Figure 3.1-1 shows the opening screen for the Comsearch Spectrum Sharing Tool. The outline of the state of Virginia serves as a place holder for a future logo. From this screen the user selects all other parameters for the analysis.

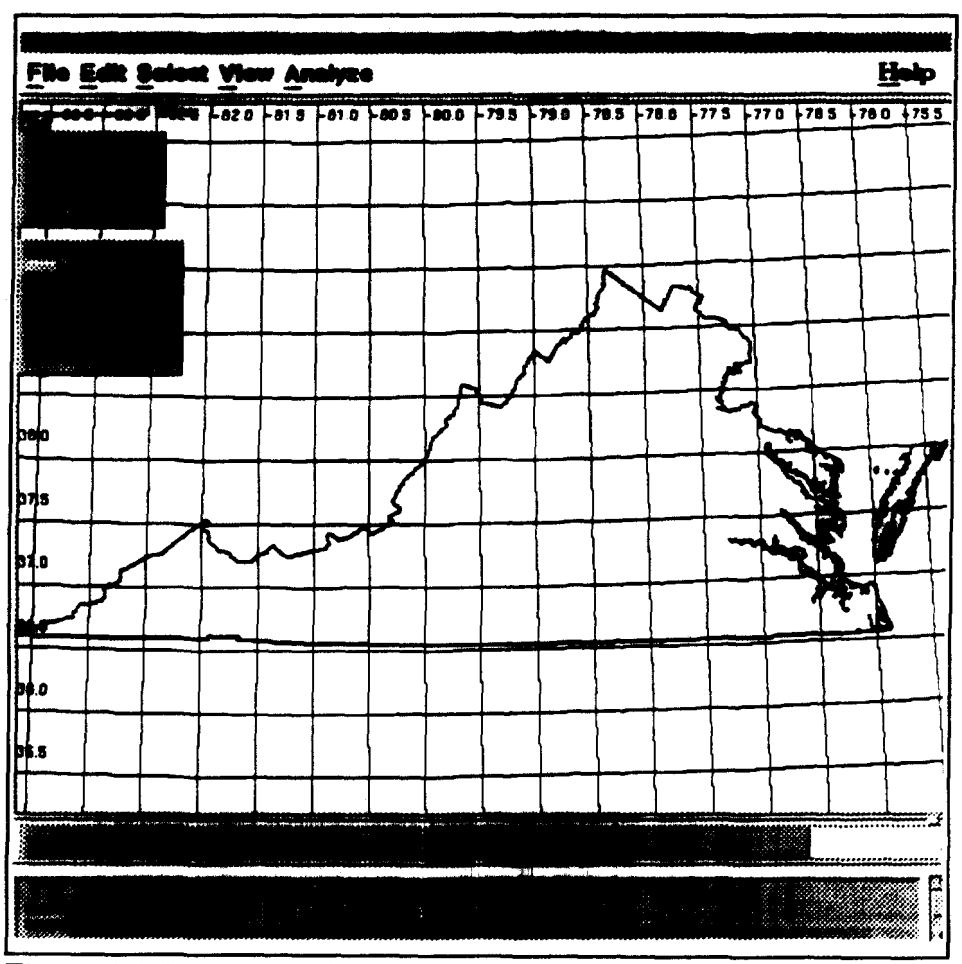


Figure 3.1-1 Comsearch Spectrum Sharing Tool Opening Screen

By selecting "New" under the "File" menu bar, the user can begin a new study. The "Load New Project" window appears and offers the user a number of choices. This screen is shown in Figure 3.1-2. The Data Directory and Data File entries are used to specify the location of the data used in the analysis and are not usually modified. The Coord Distance (km) entry is for the user to specify the desired coordination distance around the selected area. If coordination distance is set to 0 km, the only microwave links included in the study will be those with at least one terminal located within the study area. If a coordination distance is selected, the tool will find the rectangle that completely encloses the study area and then expand the rectangle by the coordination distance. All microwave links with at least one terminal within the expanded rectangle will be included in the study. The FCC has specified the coordination distance to use in the frequency coordination and the values range from 99 to 313 km depending on the PCS antenna height and power.[5] The area selections include: MTA, BTA, BTA, State, and County.

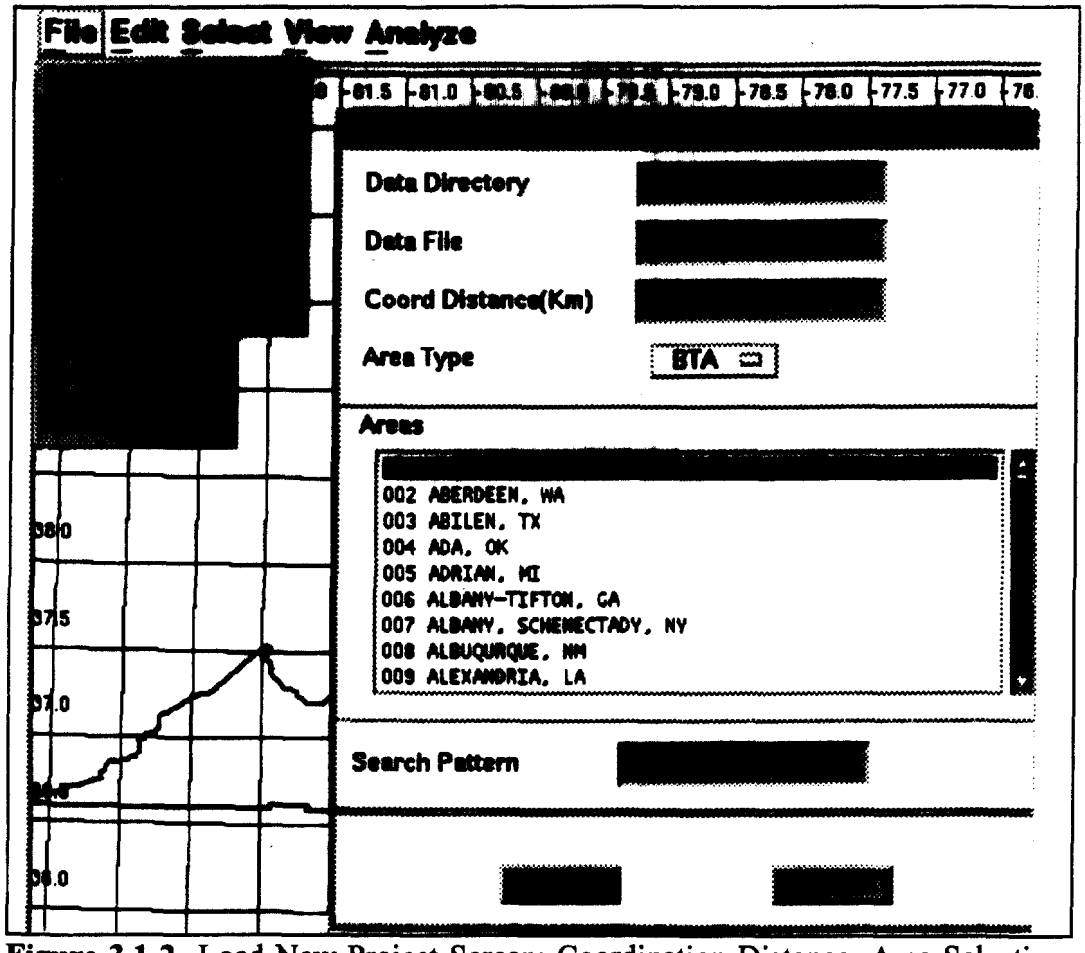


Figure 3.1-2 Load New Project Screen: Coordination Distance, Area Selection

[5] **Second Report and Order**, General Docket No. 90-314, Federal Communications Commission, Washington, DC, September 23, 1993, Appendix A: Final Rules, pg. 31.

After the study area and coordination distance have been selected, the user can select the PCS technical parameters for the analysis. Figure 3.1-3 shows the selection screen used to enter these choices. The current version of the Spectrum Sharing Tool assumes an omnidirectional Base Station antenna. The "Base TX Power" entered in this screen is the total EIRP for each PCS Base Station. The "Max Mobile Tx Power" is also the total EIRP for all the mobiles in each cell. The "Digital Modul. Reduction" entry represents the digital modulation reduction used to account for the reduced interference into analog microwave systems from digital interferers due to the spectrum spreading. Comsearch is currently using the processing gain of the PCS signal for this factor. For this study, the 1.25 MHz CDMA was assigned a digital modulation reduction of 18 dB and the 200 kHz TDMA system used a 6 dB reduction.

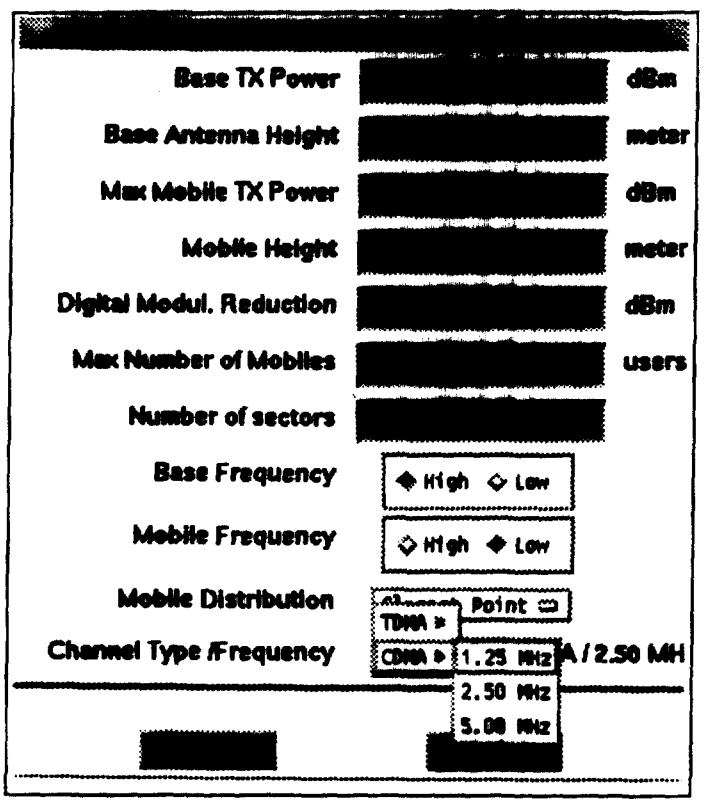


Figure 3.1-3 PCS Technical Parameter Selections

The "Base Frequency" and "Mobile Frequency" selections give the user the option of operating all base stations on the high or low frequencies, (e.g., bases could operate 1960-1970 MHz or 1880-1890 MHz.) The "Mobile Distribution" gives the choice of where to place the mobile units for the analysis. The "closest point" selection places all the mobile units at the edge of the cell along the line that connects the microwave receiver being analyzed with each base station. (If the microwave receiver is in the cell, the mobiles are located at the base station.) The "Channel Type/Frequency" selection gives the user the choice of the following PCS technologies: TDMA - 200, 400, 600 kHz; or CDMA - 1.25, 2.5, 5.0 MHz.

Once the PCS parameters have been selected, the user has to choose the type of cell layout to use in the analysis. Of the four selections shown in Figure 3.1-4, only two are currently working. The "Uniform Cells" selection gives the user the option of specifying a cell radius to apply to the entire study area. The uniform cells start at the upper left hand corner of the study area and provide a uniform coverage with all cells having the same radius. The "Import Cells" option gives the user the ability to import a cell layout from any other source. The imported cell layout must contain the following items:

- Cell Number
- Cell Latitude
- Cell Longitude
- Base Station Antenna Height
- Cell Radius.

The imported cell file is a comma separated, ASCII text file that can be produced on any spreadsheet package. The Base Station Antenna Height entry in the imported cell layout takes precedence over any height entered in the PCS parameter selection.

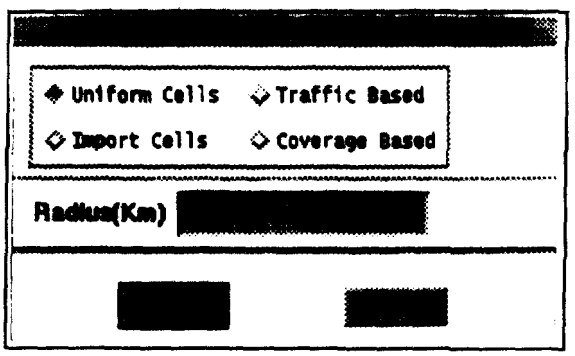


Figure 3.1-4 Cell Layout Screen

The "Traffic Based" cell layout feature is currently under development and will allow the user to define a cell layout based on the demographics of the study area. This feature will use the 1990 Census Data and offer the ability to design systems based on projected traffic. The feature will also allow the user the ability to examine the following demographic information on a census tract level:

- Population
- Number of Housing Units
- Per Capita Income
- Housing Value
- Travel Time to Work.

Once the study area, PCS parameters, and cell layout have been selected, the user must select the spectrum allocation for the study. Figure 3.1-5 shows the spectrum allocation selection screen. The spectrum allocation selections are based on the blocks defined by the FCC and the custom allocations generated for this study. The 30 MHz allocation will be auctioned/allocated on an MTA basis, while the 20 and 10 MHz allocation will be based on the BTA.

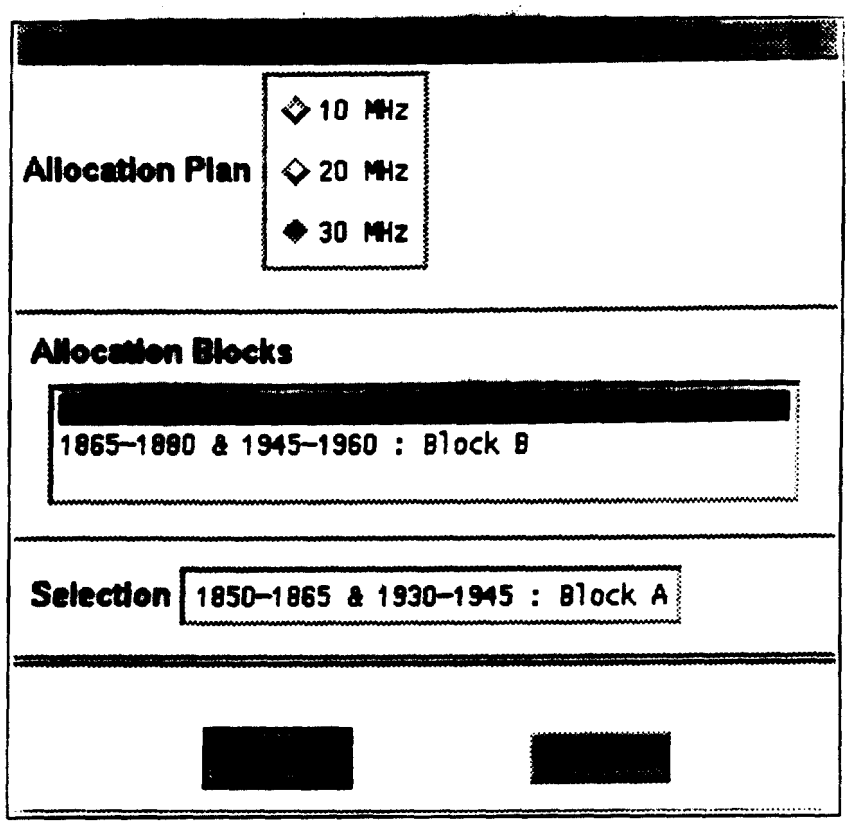
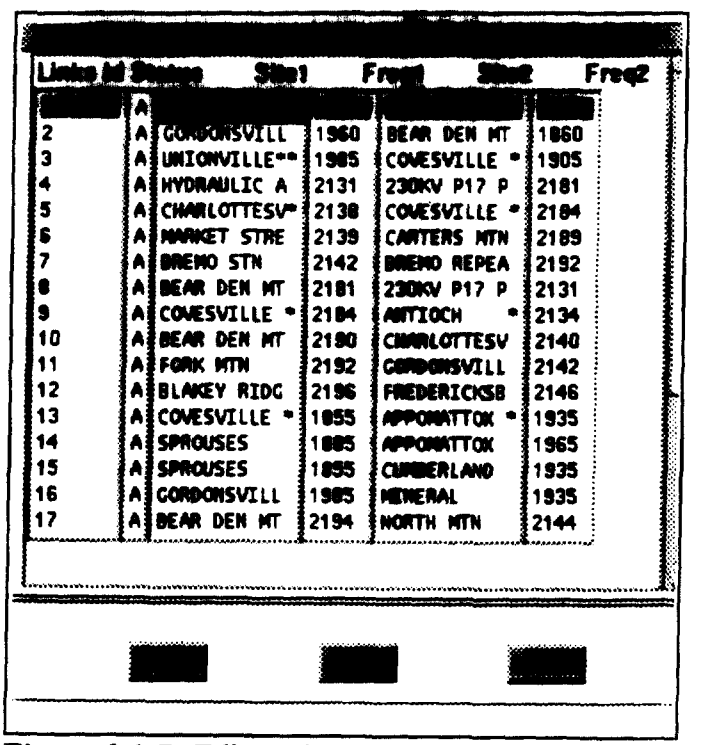


Figure 3.1-5 Spectrum Allocation Selection

Figure 3.1-6 shows the "Select Interference" screen that is used to choose the interference criteria for the analysis. The "Threshold Degradation" allows the user to select between the 6 dB and 10 dB criteria that was discussed in Section 2.7-2. The "Fade Margin" selection gives the user the option of using the "excess fade margin" that was discussed in Section 2.7-4. The "Polarization" option gives the user the option of specifying co-polarization (worst case) or cross-polarization (impossible to implement because the analysis assumes the PCS system is cross-polarized to every microwave link.) The "Propagation Model" selection gives the following choices: TR14/11 (suburban Hata to the horizon, then forward scatter loss), FSL (free space loss, absolute worst case), Extended Hata (CCIR extension of Hata to 100 km), OH-LOSS (Comsearch terrain based propagation using Tech Note 101 and CCIR.) This study used the TR14/11 propagation model. The analysis used the 3 arc-second digital terrain data for the TR14/11 model to determine the elevation of each PCS Base Station. The Base Station elevation is used

in determining the horizon distance between a Base Station and each microwave receiver in the study.

The interference criteria selection completes the basic input parameters for a spectrum sharing study. At this point the screen will display the study area (MTA, BTA, BTA State, County), all the microwave links in the area, and the cell layout. The number of microwave links considered in the analysis or displayed on the screen can be modified using the "Edit Links" feature. The link editing can be applied to all the links or selected groups of links. Figure 3.1-7 shows the display for the "Edit Links - All" feature. This gives the link id number, the status (A - applied to the analysis, D - deleted from analysis), the site names, and the receive frequency for each site. If the number of microwave links in the study area is small, this can be used for link editing.



Link Id	Status	Site1	Freq1	Site2	Freq2
2	A	GORDONSVILL	1960	BEAR DEN MT	1860
3	A	UNIONVILLE**	1985	COVESVILLE *	1905
4	A	HYDRAULIC A	2131	230KV P17 P	2181
5	A	CHARLOTTESV*	2138	COVESVILLE *	2184
6	A	MARKET STRE	2139	CARTERS MTN	2189
7	A	BREMO STN	2142	BREMO REPEA	2192
8	A	BEAR DEN MT	2181	230KV P17 P	2131
9	A	COVESVILLE *	2184	ANTIOCH *	2134
10	A	BEAR DEN MT	2190	CHARLOTTESV	2140
11	A	FORK MTN	2192	GORDONSVILL	2142
12	A	BLAKEY RIDG	2196	FREDERICKSB	2146
13	A	COVESVILLE *	1955	APPOMATTOX *	1935
14	A	SPROUSES	1885	APPOMATTOX	1965
15	A	SPROUSES	1855	CUMBERLAND	1935
16	A	GORDONSVILL	1985	MINERAL	1935
17	A	BEAR DEN MT	2194	NORTH MTN	2144

Figure 3.1-7 Edit Links - All Display

The "Edit Links - All" can be difficult to manipulate if there is a large number of microwave links in the study area. Another link editing option allows the user to include a reduced number of microwave links in the display or study. Figure 3.1-8 shows the "Edit Links - Selected" option screen. The following options are offered:

- Spectrum: Displays only links within +/- 10 MHz of Selected Spectrum
- Public Safety: Displays only links operated by Public Safety users

- Owner: Allows the user to consider links by selected owners
- Analog: Only considers analog microwave receivers
- Digital: Only considers digital microwave receivers
- Frequency: Allows the user to specify exact frequency ranges.

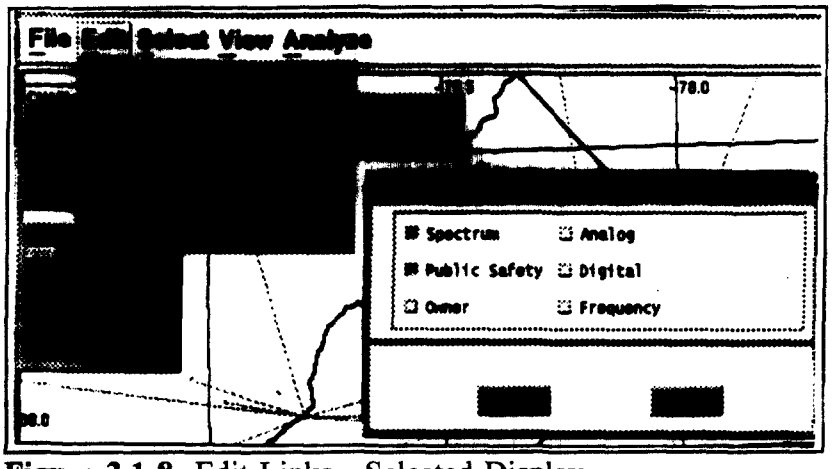


Figure 3.1-8 Edit Links - Selected Display

These choices can be combined, allowing the user to display/analyze any appropriate combination of factors. For example, the analysis could be restricted to Digital Microwave Links operated by Public Safety Users in the 1850-1860/1930-1940 MHz range. This feature will allow the user to perform custom analyses as required to support microwave relocation planning and rollout of PCS systems.

Figures 3.1-10 and 3.1-11 show the selection screens for the Select Links by Owner and Select Links by Frequency options.The results in this study only display the microwave links that are within +/- 10 MHz of the selected spectrum. This was done to minimize the number of microwave links displayed on the screen to present a clearer picture of the New York BTA.

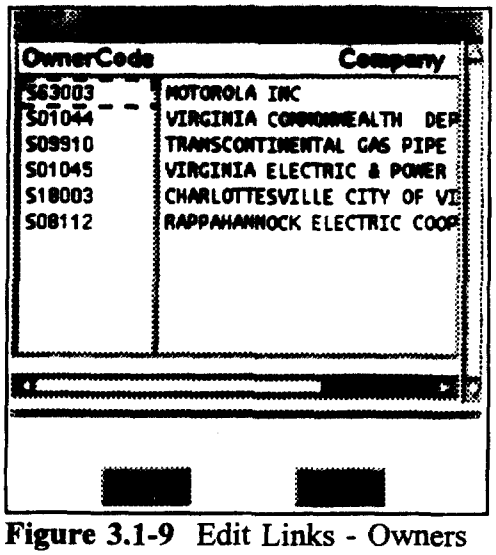


Figure 3.1-9 Edit Links - Owners

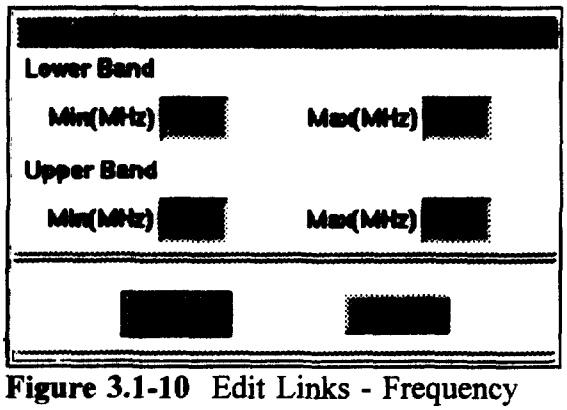


Figure 3.1-10 Edit Links - Frequency

3.2 Analysis Procedure

Once all the parameters have been selected, the analysis can be started. The Comsearch Spectrum Sharing Tool analysis is performed separately for the PCS Base Stations and for the PCS Mobile Stations. When terrain information is available, the elevation of the PCS Base Station is determined and stored in the cell parameters. The first step in the analysis determines which microwave receivers would be affected by either the base or mobile stations. This is done by comparing the microwave receiver frequency with the selected spectrum (+/- 10 MHz.) This allows the software to skip the analysis for receivers outside the selected spectrum and improves the performance of the software. (The tradeoff of this approach is that to examine all the spectrum allocations within a given market, a user would have to run the analysis 9 times - seven licensed bands and the two unlicensed bands.)

Once the program has identified the microwave receivers affected by the selected parameters, the analysis begins for the PCS Base Stations. For each microwave receiver affected, the distance and azimuth from the microwave receiver to each cell is calculated. The distance is used in determining the path loss and the azimuth is used to determine the microwave antenna gain in that direction. Any required adjustments such as Digital Modulation Reduction, 10 dB Threshold Degradation, or 5 9's or 6 9's Fade Margin are used to modify the microwave receiver's interference objective. (The adjustments could have been made to the PCS EIRP as well, but the microwave receiver adjustment approach simplified the implementation.)

The PCS Base Station parameters such as transmitted power and antenna height are used to determine the receive signal level at the microwave receiver for each cell in the PCS system. The entire PCS system is assumed to be operating at the same frequency as the victim microwave. The total PCS power received at the microwave receiver is then determined based on the specific antenna pattern and fixed losses at that site. If the total PCS power is less than the interference objective for the particular radio, no interference is produced and the analysis continues to the next microwave receiver.

If the total PCS power received at the microwave receiver exceeds the interference objective, then the receive signal levels from the PCS cells are sorted in descending order (highest-to-lowest.) The cell with the highest contribution to the total PCS power is then removed from the list and the sum is calculated again. If the sum is still greater than the interference objective, the next highest power cell is removed from the list. This continues until the total PCS power received at the microwave receiver is less than the interference objective. The cells that are excluded during this process are prohibited from using certain frequencies because they would cause, or contribute to, harmful interference at the microwave site. The following frequency offsets are checked for each microwave receiver:

- 0 MHz
- +/- 2.5 MHz
- +/- 5.0 MHz
- +/- 10.0 MHz.

These offsets are checked by having four different interference objectives for each microwave receiver, corresponding to the appropriate frequency offsets. The unavailable frequencies are stored with the cell information. This procedure is then repeated for every microwave receiver within the study parameters. The same process is also repeated for the Mobile Stations.

Once the analysis is completed, the results are displayed by changing the color of the cells to show the amount of spectrum available in each cell. A seven color scale was selected to maximize the difference in color between steps and still produce acceptable printed results. This requires that the available spectrum be divided into seven different states ranging from 100 % available (green) to 0 % available (red.) The interim steps increase by 14.29 % (because 100÷7=14.29) and range from pink to light green. The available spectrum is also divided by the frequency allocation plan to determine the number of full duplex channels available. For example, the 20 MHz allocation can support 8 full duplex 1.25 MHz CDMA channels. The upper and lower bands of the allocation are divided into 8 equally spaced channels. Both the upper and lower channel must be available to use a full duplex channel. If all 8 of the channels at the upper part of the band (e.g.,1960-1970 MHz) are not available, then there are no channels available at that cell, although the 8 channels in the lower part of the band are available.

The spectrum sharing analysis also displays the cell statistics in addition to the color display. The cell statistics show the number of cells associated with each percentage of spectrum available. The cell statistics are presented as a table somewhere on the plot and shows the number of full duplex channels associated with each percentage. These statistics show the percentages that corresponding to the color scale and indicate the number of channels available. There is also a means of attaching text to this box to add additional information to keep track of the parameters used in the analysis.

The next sections will present the results of the New York BTA Spectrum Sharing study. The results will be presented by the color plots that are produced as the output of the Spectrum Sharing Tool. Each of the following sections will contain the results of running the sharing study based on a certain spectrum allocation and access technology and determining the number of microwave links required to have 25 % of the allocated spectrum available **everywhere** in the BTA. This requires relocating every link that prevents any cell in the area from meeting the spectrum availability goal. Links are removed from the analysis by using the "Edit Link" functions described in Section 3.1.

Figure 3.2-1 shows the New York BTA with the 50 km coordination distance. There are a total of 378 microwave links in the 1850-1990 & 2130-2150/2180-2200 MHz bands that have at least one terminal within the 50 km coordination distance of the New York BTA. All other plots of the New York area in this report will only display the microwave links within +/- 10 MHz of the spectrum allocation under test.

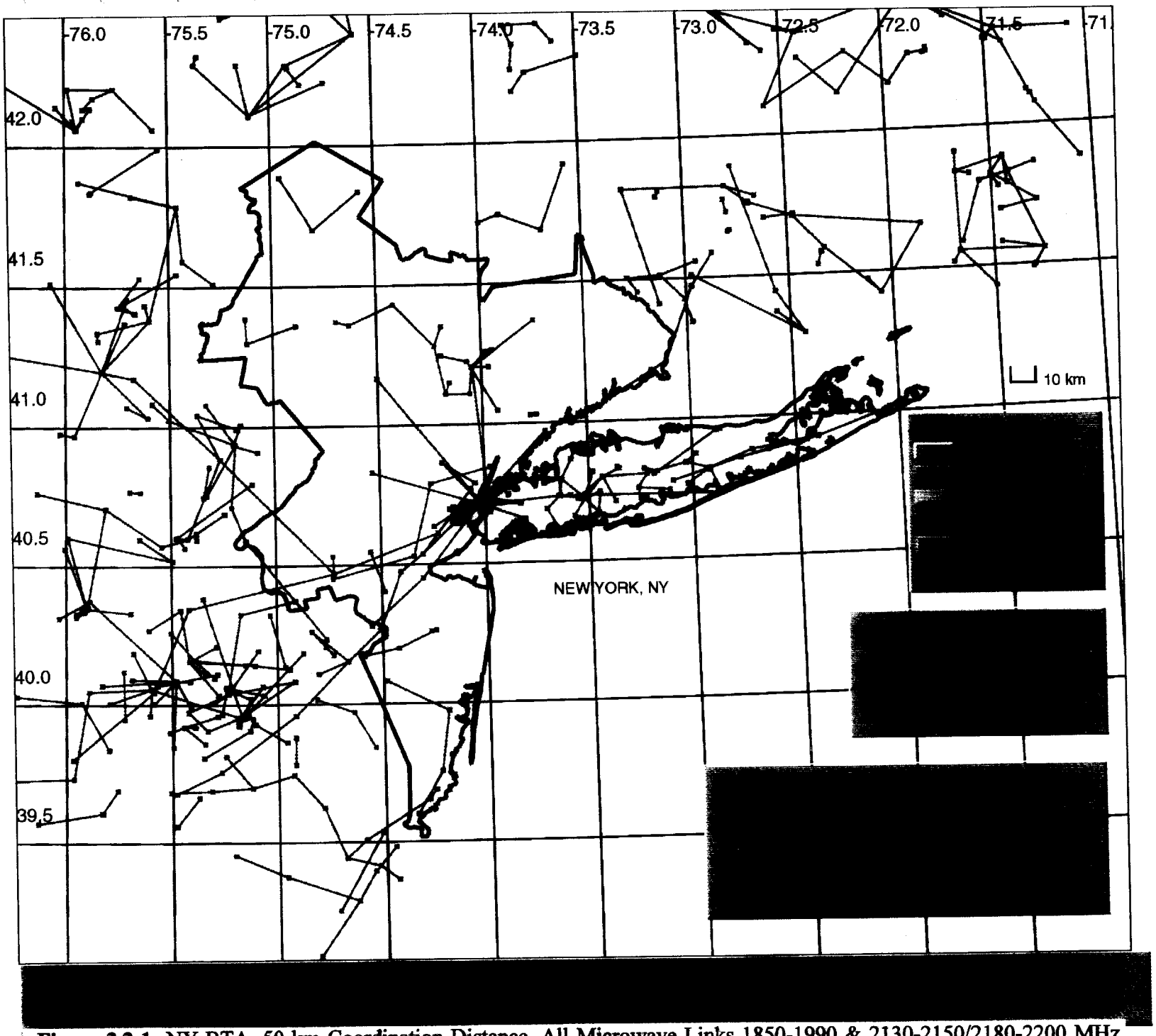


Figure 3.2-1 NY BTA, 50 km Coordination Distance, All Microwave Links 1850-1990 & 2130-2150/2180-2200 MHz

3.3 Existing Spectrum Allocation - 1.25 MHz CDMA

This section presents the results of the existing PCS spectrum allocations. The following allocations are analyzed:

- 1850-1865/1930-1945 MHz
- 1865-1880/1945-1960 MHz
- 1880-1890/1960-1970 MHz.

The first spectrum allocation test used the following parameters:

• Uniform Cell Distribution:	2.4 km radius
• Base Station EIRP:	40.0 dBm
• Base Station Height:	30 m
• Mobile Station EIRP:	40.0 dBm
• Mobile Station Height:	1.6 m
• Coordination Distance:	50 km
• Fade Margin:	None
• Digital Modulation Reduction:	18 dB
• Interference Criteria:	6 dB Threshold Degradation
• PCS System Technology:	1.25 MHz CDMA.

3.3.1 1850-1865/1930-1945 MHz Allocation - CDMA

The 2.4 km radius uniform cell distribution requires 1628 cells to cover the New York BTA. The initial run under these assumptions shows that there are 1628 cells with no spectrum available (100 %.) This result is shown on Figure 3.3.1-1. The only microwave links shown in this figure are those within the analysis band (1850-1875/1920-1955 MHz.) The small blue squares that are not connected by blue lines are the terminals associated with links not in the analysis band.

In order to meet the 25 % spectrum available requirement, the spectrum sharing analysis was then run a number of times with various microwave links removed. This continued until all the red cells (0 spectrum available) were removed from the study area and the 25 % spectrum availability goal was met. The result of this process is shown in Figure 3.3.1-2.

A total of 33 microwave links were removed to meet the 25 % spectrum availability requirement for the 1850-1865/1930-1945 MHz allocation. This analysis considered 77 microwave links in the analysis band (+/- 10 MHz.)

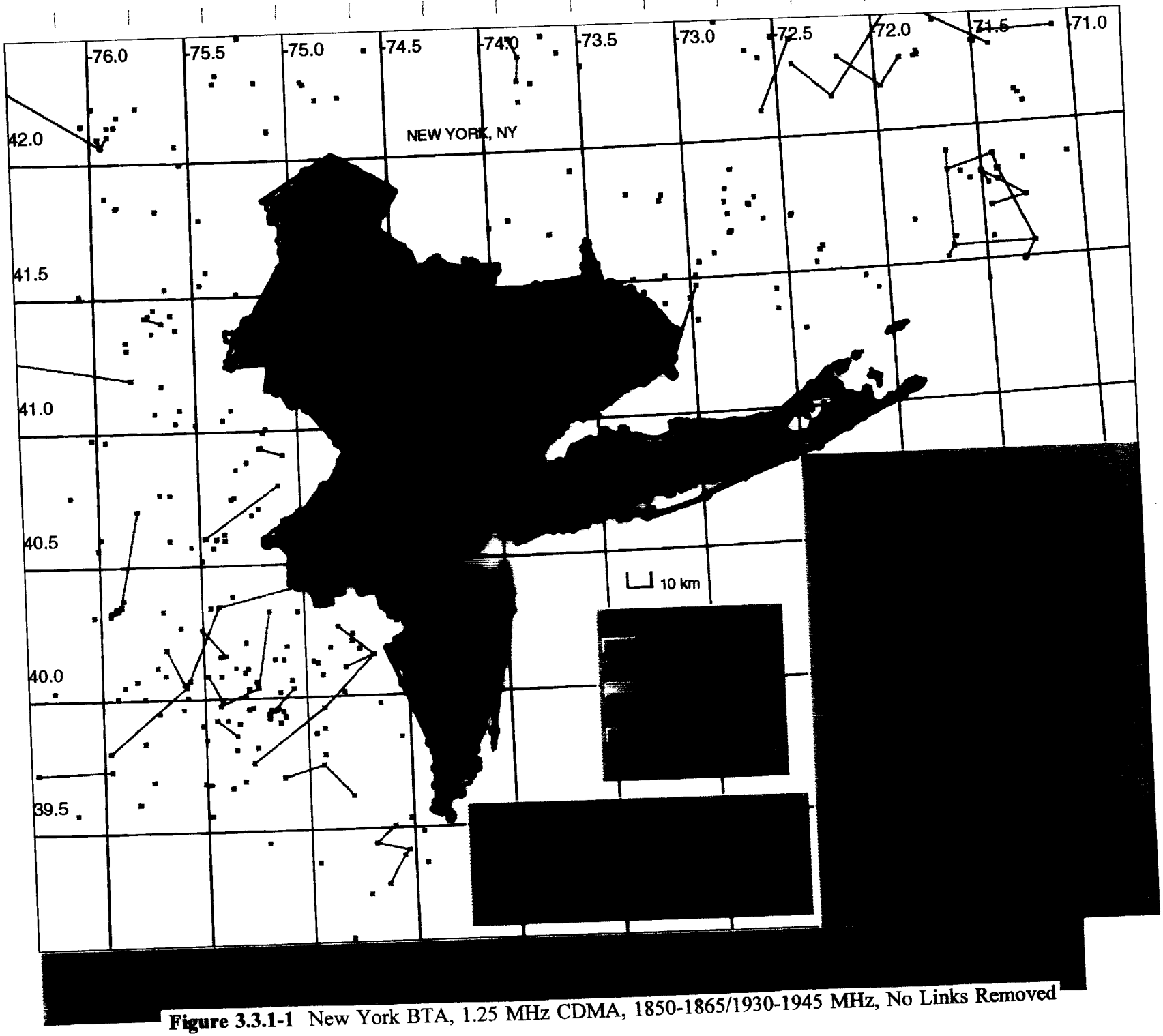


Figure 3.3.1-1 New York BTA, 1.25 MHz CDMA, 1850-1865/1930-1945 MHz, No Links Removed

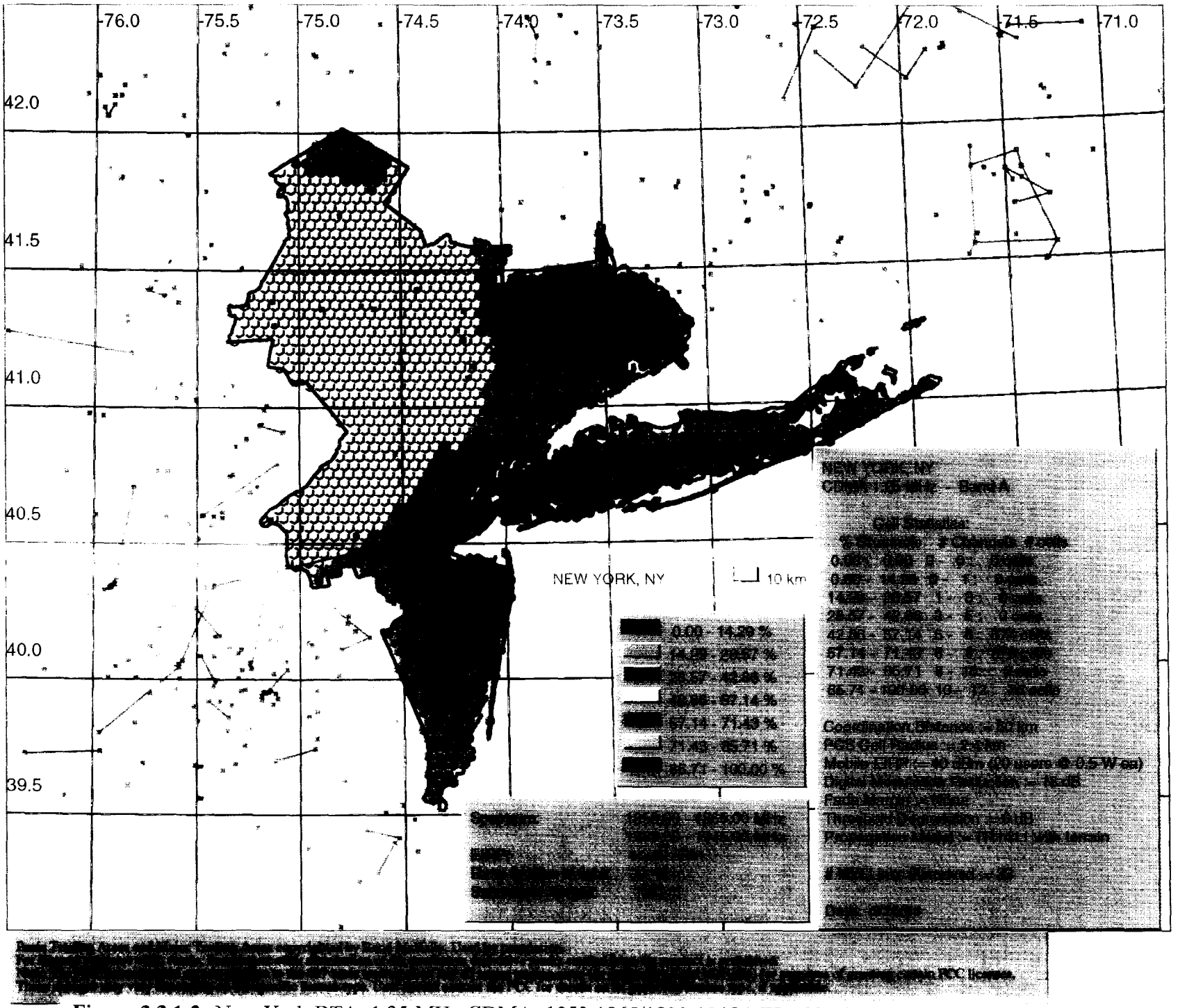


Figure 3.3.1-2 New York BTA, 1.25 MHz CDMA, 1850-1865/1930-1945 MHz, 33 Links Removed, 25 % Clear

3.3.2 1865-1880/1945-1960 MHz Allocation - CDMA

This test used the same parameters as the first test:

- Uniform Cell Distribution: 2.4 km radius
- Base Station EIRP: 40.4 dBm
- Base Station Height: 30 m
- Mobile Station EIRP: 40.0 dBm
- Mobile Station Height: 1.6 m
- Coordination Distance: 50 km
- Fade Margin: None
- Digital Modulation Reduction: 18 dB
- Interference Criteria: 6 dB Threshold Degradation
- PCS System Technology: 1.25 MHz CDMA.

Figure 3.3.2-1 shows the initial results for this allocation and the CDMA assumptions. There are 1593 (out of 1628) cells with no spectrum available.

Figure 3.3.2-2 shows the result of removing 65 microwave links to meet the 25 % spectrum available goal. There were a total of 110 microwave links considered within +/- 10 MHz of the allocation.

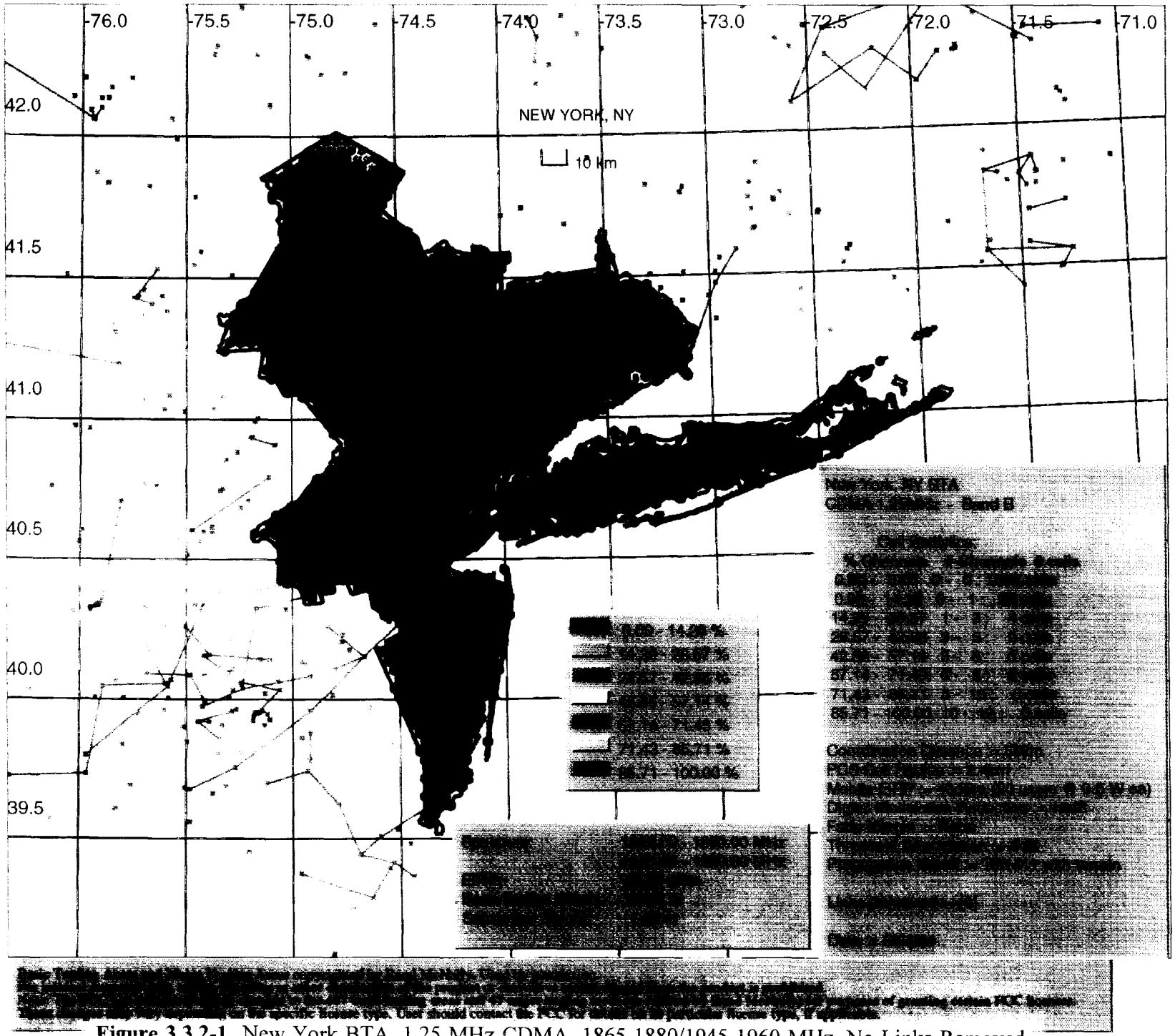


Figure 3.3.2-1 New York BTA, 1.25 MHz CDMA, 1865-1880/1945-1960 MHz, No Links Removed

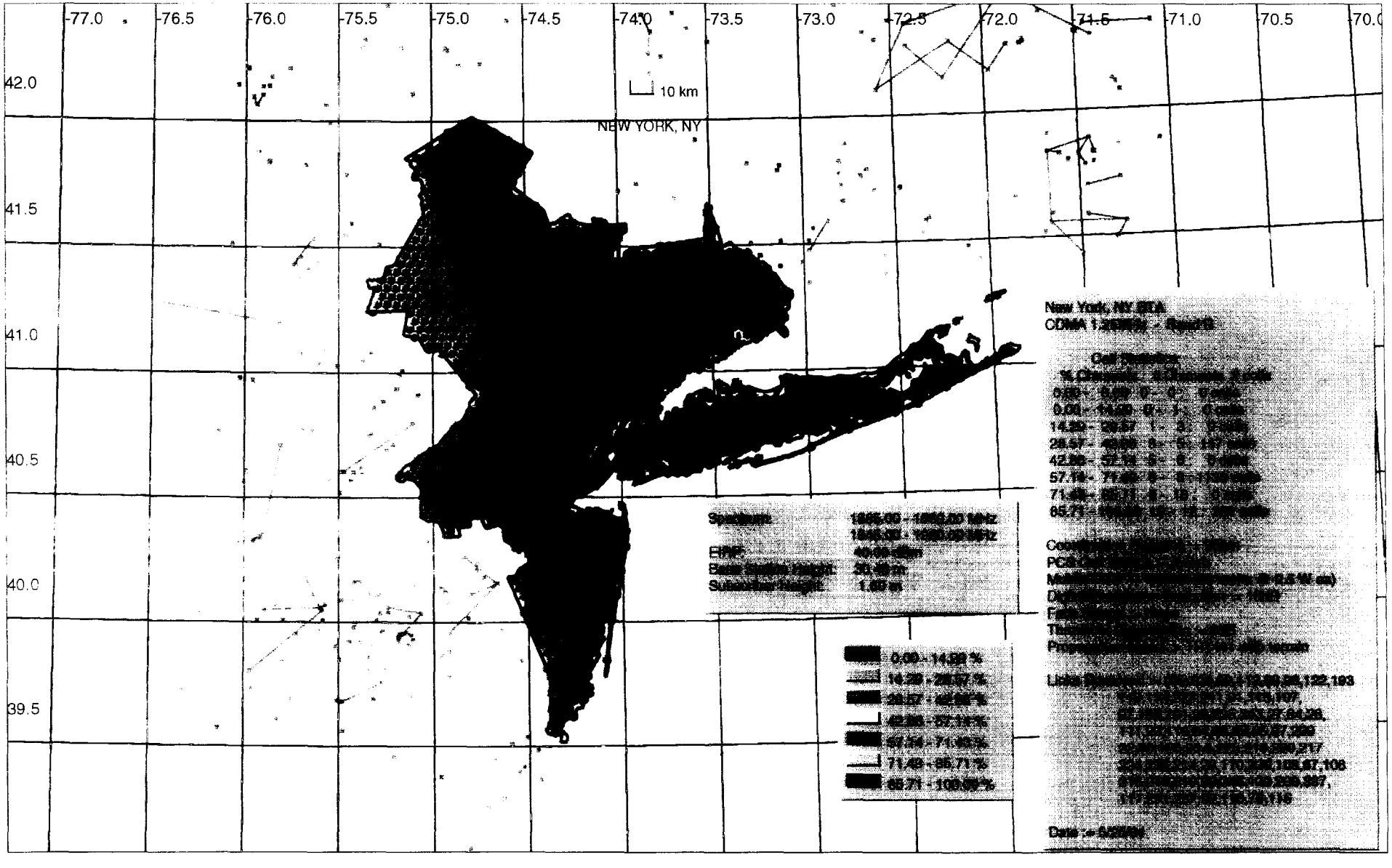


Figure 3.3.2-2 New York BTA, 1.25 MHz CDMA, 1865-1880/1945-1960 MHz, 65 Links Removed, 25 % Clear

3.3.3 1880-1890/1960-1970 MHz Allocation - CDMA

This test used the same parameters as the first test:

- Uniform Cell Distribution: 2.4 km radius
- Base Station EIRP: 40.4 dBm
- Base Station Height: 30 m
- Mobile Station EIRP: 40.0 dBm
- Mobile Station Height: 1.6 m
- Coordination Distance: 50 km
- Fade Margin: None
- Digital Modulation Reduction: 18 dB
- Interference Criteria: 6 dB Threshold Degradation
- PCS System Technology: 1.25 MHz CDMA.

Figure 3.3.3-1 shows the initial results for this allocation and the CDMA assumptions. There is no spectrum available based on these assumptions.

Figure 3.3.3-2 shows the result of removing 49 microwave links to meet the 25 % spectrum available goal. There were a total of 91 microwave links considered within +/- 10 MHz of the allocation.

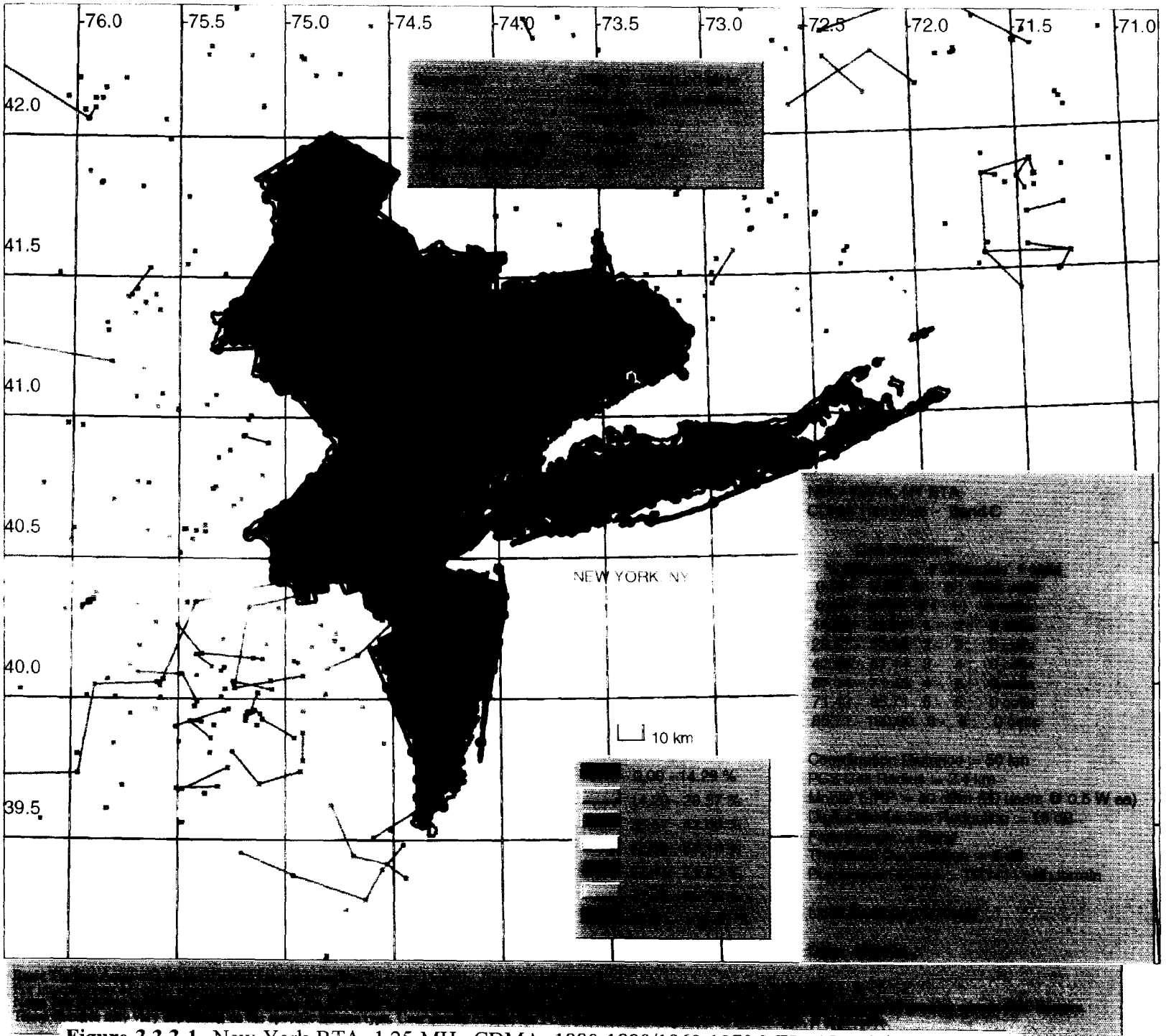


Figure 3.3.3-1 New York BTA, 1.25 MHz CDMA, 1880-1890/1960-1970 MHz, No Links Removed

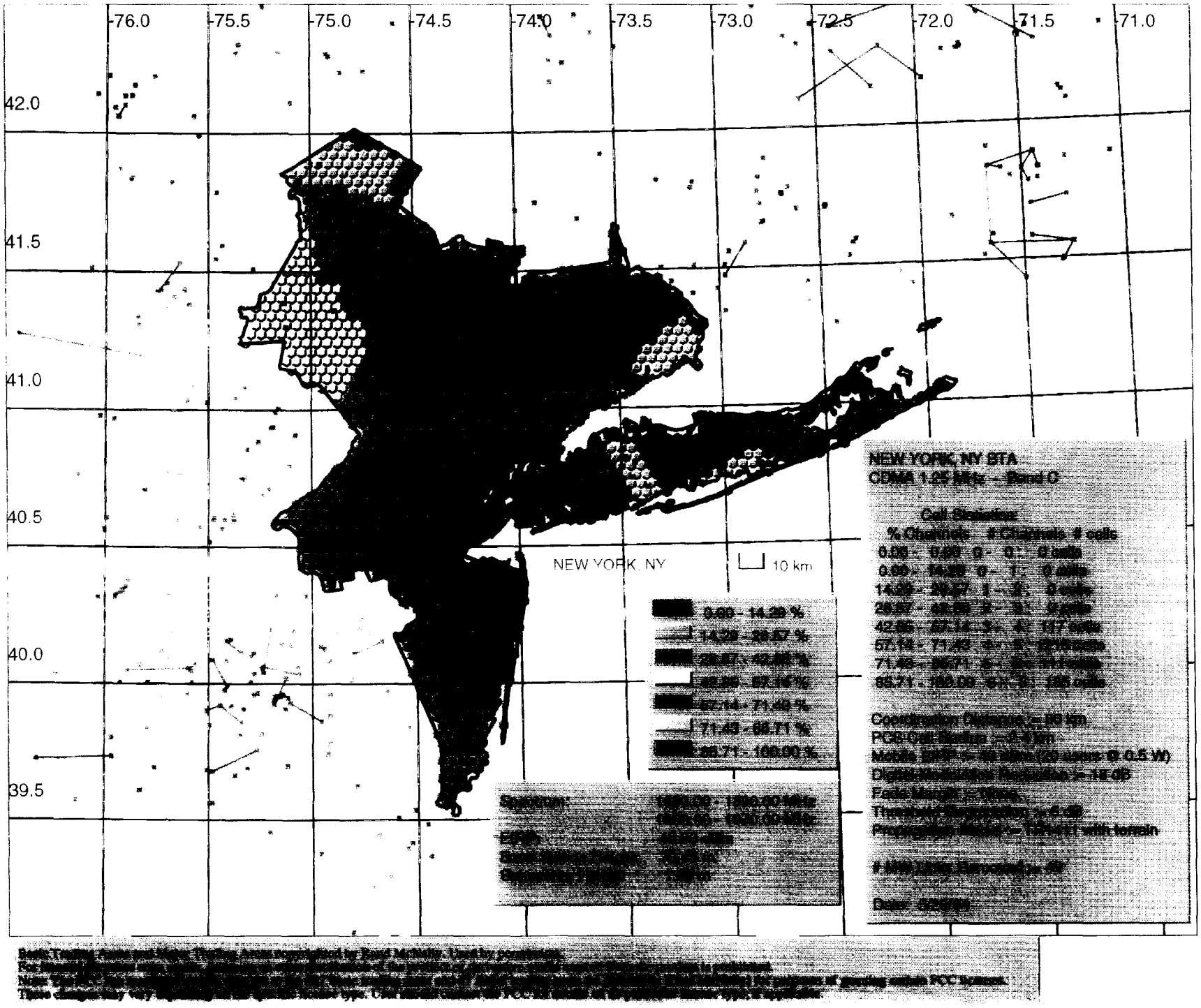


Figure 3.3.3-2 New York BTA, 1.25 MHz CDMA, 1880-1890/1960-1970 MHz, 49 Links Removed, 25 % Clear

3.4 Proposed Three 30 MHz Allocations - 1.25 MHz CDMA

This section presents the results of the proposed three 30 MHz PCS spectrum allocations. The following allocations are analyzed:

- 1850-1865/1930-1945 MHz
- 1865-1880/1945-1960 MHz
- 1880-1895/1960-1975 MHz.

This spectrum sharing test used the following parameters:

• Uniform Cell Distribution:	2.4 km radius
• Base Station EIRP:	40.4 dBm
• Base Station Height:	30 m
• Mobile Station EIRP:	40.0 dBm
• Mobile Station Height:	1.6 m
• Coordination Distance:	50 km
• Fade Margin:	None
• Digital Modulation Reduction:	18 dB
• Interference Criteria:	6 dB Threshold Degradation
• PCS System Technology:	1.25 MHz CDMA.

These are the same parameters used in the previous section. The first two allocations are the same in both cases. The 1850-1865/1930-1945 MHz allocation had no spectrum available in the initial run and required the relocation of 33 microwave links to meet the 25 % spectrum availability goal. The 1865-1880/1945-1960 MHz allocation had no spectrum available in 1593 cells and needed to relocate 65 links to meet the 25 % goal.

The proposed 1880-1895/1960-1975 MHz allocation has no spectrum available in the initial run and requires the relocation of 52 microwave links to meet the 25 % spectrum availability objective. There were a total of 106 microwave links considered in the analysis. The additional 10 MHz for this allocation required the relocation of an additional 3 microwave links compared with the 20 MHz allocation 1880-1890/1960-1970 MHz. These results are presented in Figures 3.4-1 and 3.4-2.

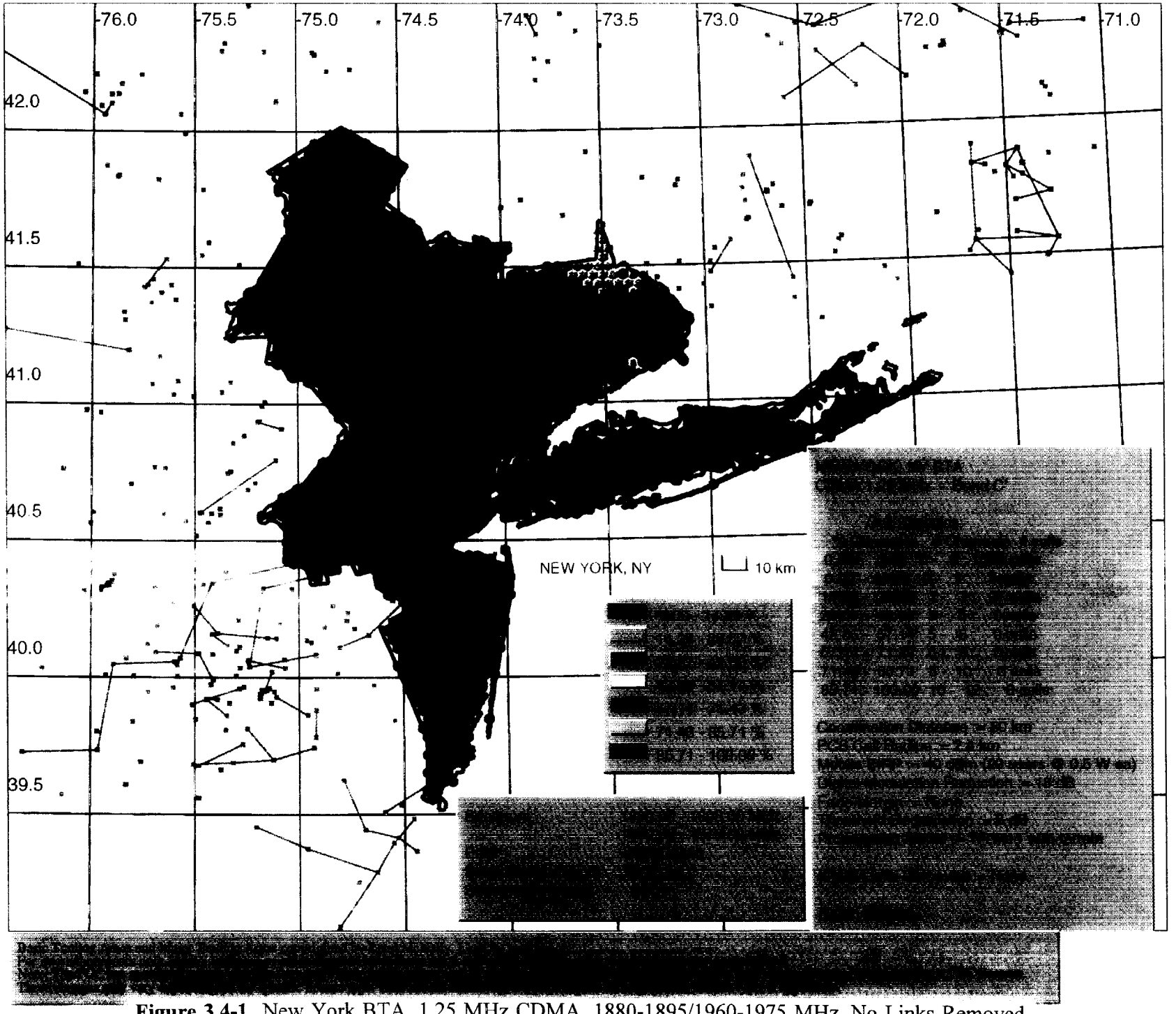


Figure 3.4-1 New York BTA, 1.25 MHz CDMA, 1880-1895/1960-1975 MHz, No Links Removed

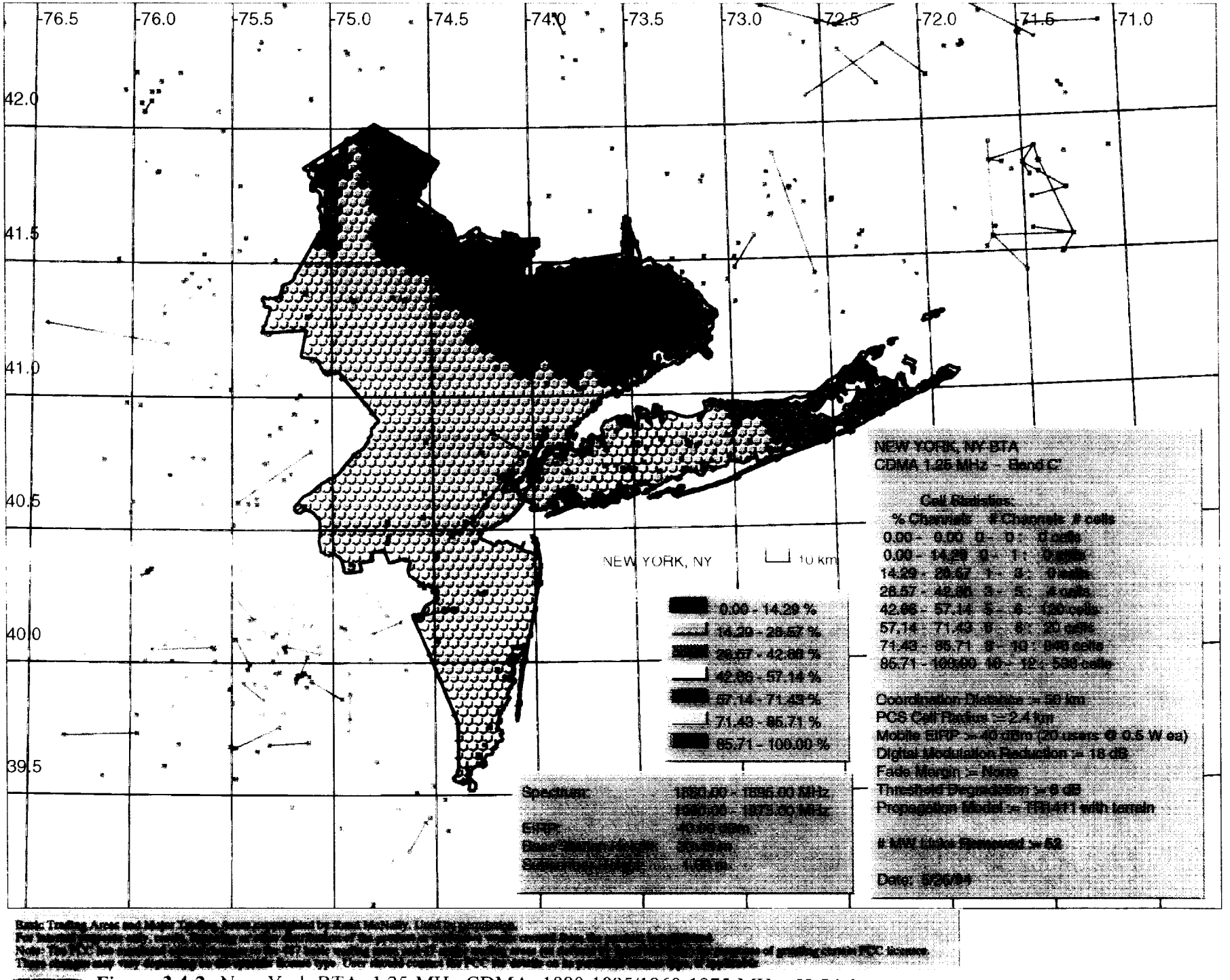


Figure 3.4-2 New York BTA, 1.25 MHz CDMA, 1880-1895/1960-1975 MHz, 52 Links Removed, 25 % Clear

3.5 Proposed Four 20 MHz Allocations - 1.25 MHz CDMA

This section presents the results of the proposed four 20 MHz PCS spectrum allocations. The following allocations are analyzed:

- 1850-1860/1930-1940 MHz
- 1860-1870/1940-1950 MHz
- 1870-1880/1950-1960 MHz
- 1880-1890/1960-1970 MHz.

This spectrum sharing test used the following parameters:

• Uniform Cell Distribution:	2.4 km radius
• Base Station EIRP:	40.4 dBm
• Base Station Height:	30 m
• Mobile Station EIRP:	40.0 dBm
• Mobile Station Height:	1.6 m
• Coordination Distance:	50 km
• Fade Margin:	None
• Digital Modulation Reduction:	18 dB
• Interference Criteria:	6 dB Threshold Degradation
• PCS System Technology:	1.25 MHz CDMA.

These are the same parameters used in the previous sections. The results for the fourth 20 MHz allocation were presented in the Section 3.3.3. That particular allocation had no spectrum available initially and required the relocation of 49 microwave links to meet the 25 % availability goal.

Figure 3.5-1 shows the results for the 1850-1860/1930-1940 MHz allocation. There is no spectrum available in the initial plot. A total of 21 microwave links (out of 55) were relocated to meet the 25 % requirement. This is shown in Figure 3.5-2.

Figure 3.5-3 shows the results for the 1860-1870/1940-1950 MHz allocation. There is no spectrum available in the initial plot. A total of 52 microwave links (out of 83) were relocated to meet the 25 % requirement. Moving these 52 links also happened to make 100 % of the spectrum available. This result is shown in Figure 3.5-4.

Figure 3.5-5 shows the results for the 1870-1880/1950-1960 MHz allocation. There is no spectrum available in the initial plot. A total of 45 (out of 94) were relocated to meet the 25 % requirement. This is shown in Figure 3.5-6.