

## Chapter 7

# Planning & Growing Networks

**Link Budgets**

**Performance Measurements**

**Re-Radiators**

# Basic Network Objectives

- The basic basic objectives of a wireless system are:
  - **COVERAGE:** provide sufficient cells to deliver RF coverage of the entire desired area
  - **BUILDING/VEHICLE PENETRATION:** deliver sufficient signal levels to adequately penetrate buildings and vehicles where appropriate
  - **TRAFFIC:** ensure that no cell captures more traffic than it can handle at the desired grade of service (i.e., blocking percentage)
  - **SCHEDULE:** construct the network and bring it to successful commercial launch at a date which will prevent significant loss of potential customers to competitors
  - **PERFORMANCE:** design, construct, and adjust the network to deliver reliable service free from excessive origination and call delivery failures, dropped calls, quality impairments, and service outages
  - **ECONOMICS:** provide return on investment sufficient to support operating and capital expenses, expand the network to take advantage of growth opportunities, and retire costs of construction prior to depreciation of the network equipment

# General Design Considerations and Examples

- Network design impacts every network objective listed on the previous page. The first three items actually drive successful network designs, while the final three are largely results of a good network design.
- The following design example in a typical large market shows the high-level planning and decision-making that goes into successful network design, and provides data to illustrate the tradeoffs involved.
- A spreadsheet file will be provided on diskette by your instructor for your own interactive use in exploring a test network design for your own market

# Section 7A

## Link Budgets

# Link Budget Example: Usage Model and Service Assumptions

- This section outlines the number of subscribers and amount of traffic by year
- This section shows the variability of outdoor and indoor signals, and the building penetration loss

| Interactive Initial System Design Example  |                          |                       |                       |                              |                                     |                  | v1.2 |
|--|--------------------------|-----------------------|-----------------------|------------------------------|-------------------------------------|------------------|------|
| fill in GREEN fields   |                          |                       |                       |                              |                                     |                  |      |
| YELLOW fields calculate automatically  |                          |                       |                       |                              |                                     |                  |      |
| <b>Step 1. Basic Business Plan Details</b>   |                          |                       |                       |                              |                                     |                  |      |
| Year   | Launch                   | 1                     | 2                     | 3                            | 4                                   | 5                |      |
| Population   | 3,886,000                | 3,949,350             | 4,012,700             | 4,076,050                    | 4,139,400                           | 4,202,750        |      |
| Penetration, %   | 0.05%                    | 1.85%                 | 3.72%                 | 5.64%                        | 7.60%                               | 9.57%            |      |
| #Customers   | 1,781                    | 72,933                | 149,453               | 229,941                      | 314,451                             | 402,360          |      |
| BH Erl/Cust  | 0.1                      | 0.05                  | 0.045                 | 0.05                         | 0.05                                | 0.05             |      |
| Total BH erl   | <b>178.1</b>             | <b>3,646.7</b>        | <b>6,725.4</b>        | <b>11,497.0</b>              | <b>15,722.6</b>                     | <b>20,118.0</b>  |      |
| <b>2. Enter building penetration loss and standard deviations from measurements.</b> |                          |                       |                       |                              |                                     |                  |      |
| <b>Composite Probability Of Service &amp; Required Fade Margin</b>                   |                          |                       |                       |                              |                                     |                  |      |
| Environment Type ("morphology")  | Building Median Loss, dB | Building Std. Dev, dB | Outdoor Std. Dev, dB. | Composite Standard Deviation | Desired Reliability at Cell Edge, % | Fade Margin, dB. |      |
| Dense Urban  | 20                       | 8                     | 8                     | <b>11.31</b>                 | 75.0%                               | <b>7.63</b>      |      |
| Urban  | 15                       | 8                     | 8                     | <b>11.31</b>                 | 75.0%                               | <b>7.63</b>      |      |
| Suburban   | 15                       | 8                     | 8                     | <b>11.31</b>                 | 75.0%                               | <b>7.63</b>      |      |
| Rural  | 10                       | 8                     | 8                     | <b>11.31</b>                 | 75.0%                               | <b>7.63</b>      |      |
| Highway  | 8                        | 6                     | 8                     | <b>10.00</b>                 | 75.0%                               | <b>6.74</b>      |      |

# Reverse Link Budget Example

| 3. Construct Link Budgets            |        |            |        |          |        |         |                               |
|--------------------------------------|--------|------------|--------|----------|--------|---------|-------------------------------|
| Reverse Link Budget                  |        |            |        |          |        |         |                               |
| Term or Factor                       | Given  | Dense Urb. | Urban  | Suburban | Rural  | Highway | Formula                       |
| MS TX Power (dbm) (+)                | 23     |            |        |          |        |         |                               |
| MS antenna gain and body loss (+/-)  | 0      |            |        |          |        |         |                               |
| MS EIRP (dBm) (+)                    |        | 23.00      | 23.00  | 23.00    | 23.00  | 23.00   | A                             |
| Fade Margin, (dB) (-)                |        | -7.63      | -7.63  | -7.63    | -7.63  | -6.74   | B                             |
| Soft Handoff Gain (dB) (+)           |        | 4          | 4      | 4        | 4      | 4       | C                             |
| Receiver Interf. Margin (dB) (-)     |        | -3         | -3     | -3       | -3     | -3      | D                             |
| Building Penetration Loss (dB) (-)   |        | -20.00     | -15.00 | -15.00   | -10.00 | -8.00   | E                             |
| BTS RX antenna gain (dBi) (+)        |        | 17         | 17     | 17       | 17     | 17      | F                             |
| BTS cable loss (dB) (-)              |        | -3         | -3     | -3       | -3     | -3      | G                             |
| kTB (dBm/14.4 KHz.)                  | -132.4 |            |        |          |        |         | H                             |
| BTS noise figure (dB)                | 6.5    |            |        |          |        |         | I                             |
| Eb/Nt (dB)                           | 5.9    |            |        |          |        |         | J                             |
| BTS RX sensitivity (dBm) (-)         |        | -120.0     | -120.0 | -120.0   | -120.0 | -120.0  | H+I+J                         |
| Survivable Uplink Path Loss (dB) (+) |        | 130.4      | 135.4  | 135.4    | 140.4  | 143.3   | A+B+C+D+E<br>+F+G-<br>(H+I+J) |

- The Reverse Link Budget describes how the energy from the phone is distributed to the base station, including the major components of loss and gain within the system

# Forward Link Budget Example

| Forward Link Budget                    |         |               |               |               |               |               |                 |
|--|---------|---------------|---------------|---------------|---------------|---------------|-----------------|
| Term or Factor                         | Given   | Dense Urb.    | Urban         | Suburban      | Rural         | Highway       | Formula         |
| BTS TX power (dBm) (+)                 |         | 45            | 45            | 45            | 45            | 45            |                 |
| BTS TX power (watts)                   |         | <b>31.62</b>  | <b>31.62</b>  | <b>31.62</b>  | <b>31.62</b>  | <b>31.62</b>  |                 |
| % Power for traffic channels           |         | 74.0%         | 74.0%         | 74.0%         | 74.0%         | 74.0%         |                 |
| Number of Traffic Channels in use      |         | 19            | 19            | 19            | 19            | 19            |                 |
| BTS cable loss (dB) (-)                |         | -3            | -3            | -3            | -3            | -3            |                 |
| BTS TX antenna gain (dBi) (+)          |         | 17            | 17            | 17            | 17            | 17            |                 |
| BTS EIRP/traffic channel (dBm) (+,-)   |         | <b>44.9</b>   | <b>44.9</b>   | <b>44.9</b>   | <b>44.9</b>   | <b>44.9</b>   | A               |
| Fade margin (dB) (-)                   |         | <b>-7.63</b>  | <b>-7.63</b>  | <b>-7.63</b>  | <b>-7.63</b>  | <b>-6.74</b>  | B               |
| Receiver interference margin (db) (-)  |         | -3            | -3            | -3            | -3            | -3            | C               |
| Building Penetration Loss (dB) (-)     |         | <b>-20.0</b>  | <b>-15.0</b>  | <b>-15.0</b>  | <b>-10.0</b>  | <b>-8.0</b>   | D               |
| MS antenna gain & body loss (dB) (+,-) |         | 0             | 0             | 0             | 0             | 0             | E               |
| kTB (dBm/14.4 KHz.)                    | -132.4  |               |               |               |               |               |                 |
| Subscriber RX noise figure (dB)        | 10.5    |               |               |               |               |               |                 |
| Eb/Nt (dB)                             | 6       |               |               |               |               |               |                 |
| Subscriber RX sensitivity (dBm) (-)    |         | <b>-115.9</b> | <b>-115.9</b> | <b>-115.9</b> | <b>-115.9</b> | <b>-115.9</b> | F               |
| Survivable Downlink Path Loss, dB (+)  |         | <b>130.2</b>  | <b>135.2</b>  | <b>135.2</b>  | <b>140.2</b>  | <b>143.1</b>  | A+B+C+D<br>+E-F |
| <b>Forward/Reverse Link Balance</b>    |         | Dense Urban   | Urban         | Suburban      | Rural         | Highway       |                 |
| Which link is dominant?                | Reverse | Reverse       | Reverse       | Reverse       | Reverse       | Reverse       |                 |
| What advantage, dB?                    | 0.2     | 0.2           | 0.2           | 0.2           | 0.2           | 0.2           |                 |

- This section shows the forward link power distribution, and compares the relative balance of the forward and reverse links

# Link Budgets: What is the Radius of a Cell?

| 4. Explore propagation model to figure coverage radius of cell. |             |             |             |              |              |
|---|-------------|-------------|-------------|--------------|--------------|
| Frequency, MHz.   | 870         |             |             |              |              |
| Subscriber Antenna Height, M                                    | 1.5         |             |             |              |              |
|   | Dense Urban | Urban       | Suburban    | Rural        | Highway      |
| Base Station Antenna Height, M                                  | 20          | 20          | 30          | 50           | 50           |
|   | Dense Urban | Urban       | Suburban    | Rural        | Highway      |
| Environmental Correction, dB                                    | -2          | -5          | -10         | -17          | -17          |
| Coverage Radius, km   | <b>1.30</b> | <b>2.17</b> | <b>6.87</b> | <b>20.86</b> | <b>25.40</b> |
| Coverage Radius, Miles  | <b>0.81</b> | <b>1.35</b> | <b>4.27</b> | <b>12.96</b> | <b>15.78</b> |

- This section uses the Okumura-Hata/Cost-231 model to describe the frequency, antenna heights, and environmental factors, and their relationship on the cell's coverage distance



# Link Budgets: Putting It All Together

- Step 4 estimates the number of cells required to serve each distinct environment within the system
- Steps 5, 6, and 7 estimate the RF coverage from each cell, and the number of cells required

| 5. Calculate number of cells required for coverage, ignoring traffic considerations.                    |             |              |              |              |              |                                   |  |
|---|-------------|--------------|--------------|--------------|--------------|-----------------------------------|--|
|   | Dense Urban | Urban        | Suburban     | Rural        | Highway      | Total # Cells Required for System |  |
| Covered Area of this type, km <sup>2</sup>  | 55          | 450          | 1700         | 3400         | 1400         |                                   |  |
| One cell's coverage in this zone, km <sup>2</sup>   | 5.35        | 14.73        | 148.46       | 1367.34      | 2026.72      |                                   |  |
| # Cells required to cover zone  | 10.3        | 30.6         | 11.5         | 2.5          | 0.7          | 55.5                              |  |
| 6. What is the traffic capacity (in erlangs) of your chosen BTS configuration, year-by-year?            |             |              |              |              |              |                                   |  |
| Year  | Launch      | 1            | 2            | 3            | 4            | 5                                 |  |
| Erlangs which one BTS can carry   | 18.3        | 18.3         | 90           | 90           | 450          | 450                               |  |
| 7, 8. What is the total busy-hour erlang traffic on your system? How many BTS are required?             |             |              |              |              |              |                                   |  |
| Year  | Launch      | 1            | 2            | 3            | 4            | 5                                 |  |
| Total System Busy-Hour Erlangs  | 178.1       | 3,646.7      | 6,725.4      | 11,497.0     | 15,722.6     | 20,118.0                          |  |
| Capacity of One BTS, erlangs  | 18.3        | 18.3         | 90           | 90           | 450          | 450                               |  |
| # BTS required to handle all the traffic  | 9.7         | 199.3        | 74.7         | 127.7        | 34.9         | 44.7                              |  |
| 9. Examine your market, #BTS required for coverage and capacity; estimate total number of BTS required. |             |              |              |              |              |                                   |  |
| Year  | Launch      | 1            | 2            | 3            | 4            | 5                                 |  |
| #BTS req'd just to achieve coverage   | 55.5        | 55.5         | 55.5         | 55.5         | 55.5         | 55.5                              |  |
| #BTS required just to carry traffic   | 9.7         | 199.3        | 74.7         | 127.7        | 34.9         | 44.7                              |  |
| <b>Estimated total #BTS required</b>  | <b>56.3</b> | <b>206.8</b> | <b>206.8</b> | <b>206.8</b> | <b>206.8</b> | <b>206.8</b>                      |  |

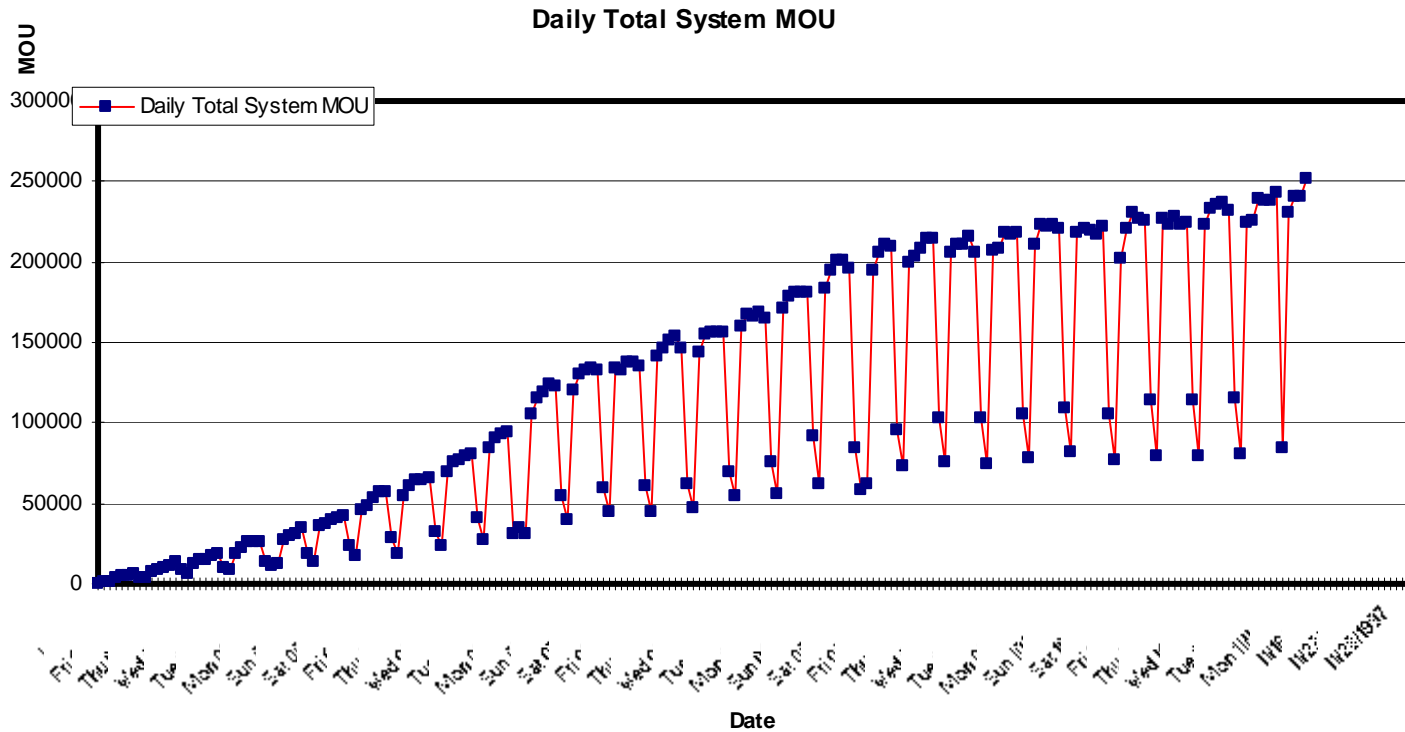
## Section 7B

**Operational Measurements  
Some Capacity Consideration**





# Total System Daily MOU Example



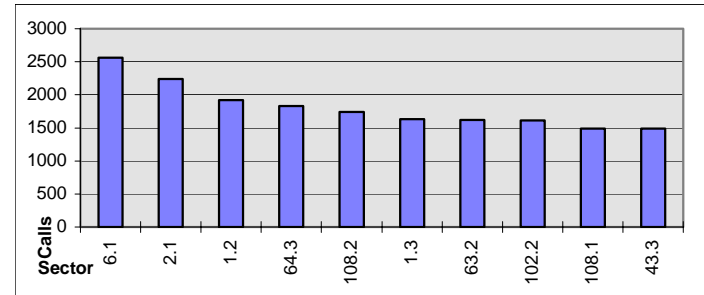
- Total system daily MOU plotted by a PCS customer

# “Top Ten” Performance Tracking Example

## Call Attempts

| Eng Site | MSC Site | Call Call Att | %Call Succ | Block Calls | %Bick Calls | Acc Fail | %Acc Fail | Drop Calls | %Drop Calls |     |
|----------|----------|---------------|------------|-------------|-------------|----------|-----------|------------|-------------|-----|
| 6.1      | 13X      | 2561          | 2234       | 87.2        | 130         | 5.1      | 130       | 5.1        | 145         | 5.7 |
| 2.1      | 2X       | 2244          | 2017       | 89.9        | 101         | 4.5      | 101       | 4.5        | 93          | 4.1 |
| 1.2      | 1Y       | 1922          | 1743       | 90.7        | 83          | 4.3      | 83        | 4.3        | 66          | 3.4 |
| 64.3     | 93Z      | 1833          | 1549       | 84.5        | 137         | 7.5      | 136       | 7.4        | 110         | 6.0 |
| 108.2    | 30Y      | 1740          | 1589       | 91.3        | 46          | 2.6      | 45        | 2.6        | 83          | 4.8 |
| 1.3      | 1Z       | 1630          | 1495       | 91.7        | 31          | 1.9      | 31        | 1.9        | 81          | 5.0 |
| 63.2     | 57Y      | 1623          | 1486       | 91.6        | 49          | 3.0      | 49        | 3.0        | 66          | 4.1 |
| 102.2    | 4Y       | 1615          | 1495       | 92.6        | 18          | 1.1      | 18        | 1.1        | 70          | 4.3 |
| 108.1    | 30X      | 1490          | 1387       | 93.1        | 27          | 1.8      | 27        | 1.8        | 54          | 3.6 |
| 43.3     | 42Z      | 1488          | 1410       | 94.8        | 4           | 0.3      | 4         | 0.3        | 53          | 3.6 |

## Call Attempts

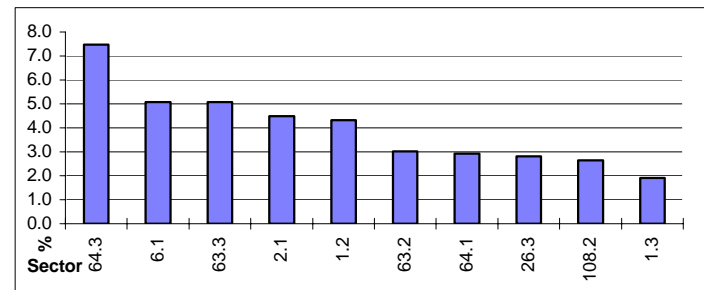


## % Blocked Calls

September 5, 1997

| Eng Site | MSC Site | Call Call Att | %Call Succ | Block Calls | %Bick Calls | Acc Fail | %Acc Fail | Drop Calls | %Drop Calls |      |
|----------|----------|---------------|------------|-------------|-------------|----------|-----------|------------|-------------|------|
| 64.3     | 93Z      | 1833          | 1549       | 84.5        | 137         | 7.5      | 136       | 7.4        | 110         | 6.0  |
| 6.1      | 13X      | 2561          | 2234       | 87.2        | 130         | 5.1      | 130       | 5.1        | 145         | 5.7  |
| 63.3     | 57Z      | 1282          | 1098       | 85.7        | 65          | 5.1      | 65        | 5.1        | 90          | 7.0  |
| 2.1      | 2X       | 2244          | 2017       | 89.9        | 101         | 4.5      | 101       | 4.5        | 93          | 4.1  |
| 1.2      | 1Y       | 1922          | 1743       | 90.7        | 83          | 4.3      | 83        | 4.3        | 66          | 3.4  |
| 63.2     | 57Y      | 1623          | 1486       | 91.6        | 49          | 3.0      | 49        | 3.0        | 66          | 4.1  |
| 64.1     | 93X      | 1027          | 926        | 90.2        | 30          | 2.9      | 30        | 2.9        | 58          | 5.7  |
| 26.3     | 35Z      | 855           | 698        | 81.6        | 24          | 2.8      | 24        | 2.8        | 112         | 13.1 |
| 108.2    | 30Y      | 1740          | 1589       | 91.3        | 46          | 2.6      | 45        | 2.6        | 83          | 4.8  |
| 1.3      | 1Z       | 1630          | 1495       | 91.7        | 31          | 1.9      | 31        | 1.9        | 81          | 5.0  |

## % Blocked Calls



- Many operators use scripts or spreadsheet macros to produce ranked lists of sites with heavy traffic, performance problems, etc.

# Lucent Reports

Highlight by CDMA\_Acs Chn\_Oc (2,1,0, ) Mean: 28.2 Std Dev: 27.83

Sort by Sys/ECP/Cell/Name/Antenna ID/Ant\_Name

| Sys/ECP/Cell/Name/Antenna ID/Ant_Name | CDMA_Acs<br>Chn_Oc | CDMA_Avg<br>Sq_DG | CDMA_Fwd<br>PCOLdur | CDMA_Fwd<br>PCOLcnt | CDMA<br>Intcpt_Msg | CDMA_Pg<br>Ch_Ocpr | CDMA_Pk<br>Acs_ChOc | CDMA_Pk<br>Pg_ChOc | CDMA_Rev<br>PCOLdur | CDMA_Rev<br>PCOLcnt |
|---------------------------------------|--------------------|-------------------|---------------------|---------------------|--------------------|--------------------|---------------------|--------------------|---------------------|---------------------|
| <b>TOTALS</b>                         | <b>5,921.00</b>    | <b>1,123,466</b>  | <b>581.00</b>       | <b>339.00</b>       | <b>0.00</b>        | <b>489,506</b>     | <b>91,989</b>       | <b>555,984</b>     | <b>305.00</b>       | <b>6.00</b>         |
| <u>179 2 1 JACKSON 1 Antenna:1</u>    | <u>30.00</u>       | <u>6,187.00</u>   | <u>12.00</u>        | <u>4.00</u>         | <u>0.00</u>        | <u>2,771.00</u>    | <u>985.00</u>       | <u>3,264.00</u>    | <u>0.00</u>         | <u>0.00</u>         |
| <u>179 2 1 JACKSON 2 Antenna:2</u>    | <u>28.00</u>       | <u>6,157.00</u>   | <u>4.00</u>         | <u>4.00</u>         | <u>0.00</u>        | <u>2,763.00</u>    | <u>563.00</u>       | <u>3,140.00</u>    | <u>0.00</u>         | <u>0.00</u>         |
| <u>179 2 1 JACKSON 3 Antenna:3</u>    | <u>10.00</u>       | <u>6,088.00</u>   | <u>2.00</u>         | <u>1.00</u>         | <u>0.00</u>        | <u>2,754.00</u>    | <u>281.00</u>       | <u>3,197.00</u>    | <u>0.00</u>         | <u>0.00</u>         |
| <u>179 2 2 WILDER 1 Antenna:1</u>     | <u>27.00</u>       | <u>6,168.00</u>   | <u>0.00</u>         | <u>0.00</u>         | <u>0.00</u>        | <u>2,795.00</u>    | <u>563.00</u>       | <u>3,125.00</u>    | <u>0.00</u>         | <u>0.00</u>         |
| <u>179 2 2 WILDER 2 Antenna:2</u>     | <u>13.00</u>       | <u>5,016.00</u>   | <u>0.00</u>         | <u>0.00</u>         | <u>0.00</u>        | <u>2,756.00</u>    | <u>422.00</u>       | <u>3,120.00</u>    | <u>0.00</u>         | <u>0.00</u>         |
| <u>179 2 2 WILDER 3 Antenna:3</u>     | <u>13.00</u>       | <u>4,818.00</u>   | <u>0.00</u>         | <u>0.00</u>         | <u>0.00</u>        | <u>2,766.00</u>    | <u>281.00</u>       | <u>3,155.00</u>    | <u>0.00</u>         | <u>0.00</u>         |
| <u>179 2 3 MARKET 1 Antenna:1</u>     | <u>4.00</u>        | <u>6,200.00</u>   | <u>0.00</u>         | <u>0.00</u>         | <u>0.00</u>        | <u>2,760.00</u>    | <u>140.00</u>       | <u>3,100.00</u>    | <u>0.00</u>         | <u>0.00</u>         |
| <u>179 2 3 MARKET 2 Antenna:2</u>     | <u>10.00</u>       | <u>6,073.00</u>   | <u>0.00</u>         | <u>0.00</u>         | <u>0.00</u>        | <u>2,731.00</u>    | <u>422.00</u>       | <u>3,195.00</u>    | <u>0.00</u>         | <u>0.00</u>         |
| <u>179 2 3 MARKET 3 Antenna:3</u>     | <u>55.00</u>       | <u>6,580.00</u>   | <u>5.00</u>         | <u>3.00</u>         | <u>0.00</u>        | <u>2,809.00</u>    | <u>845.00</u>       | <u>3,391.00</u>    | <u>0.00</u>         | <u>0.00</u>         |

Highlight by %CDMA Est Calls (2,1,0, ) Mean: 96.71 Std Dev: 1.22

Sort by %CDMA Est Calls

| Sys/ECP/Cell/Name/Label     | %CDMA<br>Est Calls | ReAcquir<br>ed_Calls | CCE<br>erlangs | CDMA_CE<br>Usage | Prim_CS<br>CE_Use | %Prim_CS<br>CE_Use | Sec_CS<br>CE_Use | %CDMA<br>SoftHO Use | %CDMA<br>SUFail | CDMA<br>Lost_Call | %CDMA<br>Lost Calls | TotCDMA<br>Failures | CDMATotl<br>Origins |
|-----------------------------|--------------------|----------------------|----------------|------------------|-------------------|--------------------|------------------|---------------------|-----------------|-------------------|---------------------|---------------------|---------------------|
| <b>TOTALS</b>               | <b>96.83</b>       | <b>2.84</b>          | <b>6,580</b>   | <b>2,368,959</b> | <b>1,451,816</b>  | <b>61.28</b>       | <b>917,143</b>   | <b>38.72</b>        | <b>2.79</b>     | <b>1,722.00</b>   | <b>1.17</b>         | <b>7,856.00</b>     | <b>5,069.00</b>     |
| <u>179 2 67 MARSHALL</u>    | <u>93.55</u>       | <u>3.22</u>          | <u>62.60</u>   | <u>22,535.00</u> | <u>9,300.00</u>   | <u>41.27</u>       | <u>13,235.00</u> | <u>58.73</u>        | <u>6.14</u>     | <u>15.00</u>      | <u>1.67</u>         | <u>95.00</u>        | <u>65.00</u>        |
| <u>179 2 10 TIGER</u>       | <u>93.58</u>       | <u>2.61</u>          | <u>128.68</u>  | <u>46,323.00</u> | <u>19,788.00</u>  | <u>42.72</u>       | <u>26,535.00</u> | <u>57.28</u>        | <u>5.68</u>     | <u>42.00</u>      | <u>2.18</u>         | <u>208.00</u>       | <u>143.00</u>       |
| <u>179 2 28 LEATHERWOOD</u> | <u>94.18</u>       | <u>3.89</u>          | <u>71.45</u>   | <u>25,722.00</u> | <u>13,689.00</u>  | <u>53.22</u>       | <u>12,033.00</u> | <u>46.78</u>        | <u>5.44</u>     | <u>20.00</u>      | <u>1.18</u>         | <u>143.00</u>       | <u>89.00</u>        |
| <u>179 2 30 SHEPHERDS</u>   | <u>94.36</u>       | <u>2.38</u>          | <u>63.54</u>   | <u>22,873.00</u> | <u>11,113.00</u>  | <u>48.59</u>       | <u>11,760.00</u> | <u>51.41</u>        | <u>3.62</u>     | <u>10.00</u>      | <u>0.89</u>         | <u>77.00</u>        | <u>47.00</u>        |
| <u>179 2 121 PENTAGON</u>   | <u>94.44</u>       | <u>5.26</u>          | <u>36.16</u>   | <u>13,016.00</u> | <u>8,448.00</u>   | <u>64.90</u>       | <u>4,568.00</u>  | <u>35.10</u>        | <u>3.68</u>     | <u>64.00</u>      | <u>5.98</u>         | <u>108.00</u>       | <u>73.00</u>        |
| <u>179 2 1 COLLEGE</u>      | <u>94.67</u>       | <u>2.65</u>          | <u>76.37</u>   | <u>27,494.00</u> | <u>15,965.00</u>  | <u>58.07</u>       | <u>11,529.00</u> | <u>41.93</u>        | <u>4.64</u>     | <u>15.00</u>      | <u>0.98</u>         | <u>102.00</u>       | <u>67.00</u>        |
| <u>179 2 45 MARYLAND</u>    | <u>94.73</u>       | <u>2.06</u>          | <u>115.21</u>  | <u>41,476.00</u> | <u>23,219.00</u>  | <u>55.98</u>       | <u>18,257.00</u> | <u>44.02</u>        | <u>5.04</u>     | <u>35.00</u>      | <u>1.44</u>         | <u>206.00</u>       | <u>141.00</u>       |
| <u>179 2 16 AVONDALE</u>    | <u>94.90</u>       | <u>2.99</u>          | <u>98.26</u>   | <u>35,372.00</u> | <u>20,059.00</u>  | <u>56.71</u>       | <u>15,313.00</u> | <u>43.29</u>        | <u>4.47</u>     | <u>41.00</u>      | <u>1.78</u>         | <u>178.00</u>       | <u>130.00</u>       |

- This figure shows various operating statistics available through AutoPace from Lucent systems
  - forward power control status
  - origination failures and dropped calls

# BTSC MO Attributes

Each attribute is a periodic counter maintained during the 15-minute automatic logging period.

| Attribute Name              | Data Type | Seq. Number   | Access, Range | Description  |
|-----------------------------|-----------|---------------|---------------|--|
| BlockedOriginationsNoTCE    | word16    | 0x0002A<br>42 | P<br>full     | Number of originations blocked because no idle channel elements were available |
| BlockedOriginationsNoFwdCap | word16    | 0x0002B<br>43 | P<br>full     | Number of originations blocked due to lack of BTS forward link excess capacity |
| BlockedOriginationsNoRevCap | word16    | 0x0002C<br>44 | P<br>full     | Number of originations blocked due to lack of reverse link capacity            |
| BlockedHandoffsNoTCE        | word16    | 0x0002D<br>45 | P<br>full     | Number of handoffs blocked because no idle channel elements were available     |
| BlockedHandoffsNoFwdCap     | word16    | 0x0002E<br>46 | P<br>full     | Number of handoffs blocked due to lack of BTS forward link excess capacity     |
| BlockedHandoffsNoRevCap     | word16    | 0x0002F<br>47 | P<br>full     | Number of handoffs blocked due to lack of reverse link capacity                |
| SuccessfulOriginations      | word16    | 0x00030<br>48 | P<br>full     | Number of successful originations  |
| SuccessfulHandoffs          | word16    | 0x00031<br>49 | P<br>full     | Number of successful handoffs  |



# Nortel FA MO Attributes

Each attribute is a periodic counter maintained during the 15-minute automatic logging period.

| FA MO Sequence Number | OM name                  | FA MO Sequence Number | OM name                  |
|-----------------------|--------------------------|-----------------------|--------------------------|
| 16                    | TCEUtilMaximum           | 2D                    | soft4softer1 Alpha       |
| 17                    | NumOfTCsConfigured       | 2E                    | soft4softer1 Beta        |
| 18                    | soft1softer1 Alpha       | 2F                    | soft4softer1 Gamma       |
| 19                    | soft1softer1 Beta        | 30                    | soft4softer2 Alpha Beta  |
| 1A                    | soft1softer1 Gamma       | 31                    | soft4softer2 Beta Gamma  |
| 1B                    | soft1softer2 Alpha Beta  | 32                    | soft4softer2 Gamma Alpha |
| 1C                    | soft1softer2 Beta Gamma  | 33                    | soft4softer3             |
| 1D                    | soft1softer2 Gamma Alpha | 34                    | soft5softer1 Alpha       |
| 1E                    | soft1softer3             | 35                    | soft5softer1 Beta        |
| 1F                    | soft2softer1 Alpha       | 36                    | soft5softer1 Gamma       |
| 20                    | soft2softer1 Beta        | 37                    | soft5softer2 Alpha Beta  |
| 21                    | soft2softer1 Gamma       | 38                    | soft5softer2 Beta Gamma  |
| 22                    | soft2softer2 Alpha Beta  | 39                    | soft5softer2 Gamma Alpha |
| 23                    | soft2softer2 Beta Gamma  | 3A                    | soft6softer1 Alpha       |
| 24                    | soft2softer2 Gamma Alpha | 3B                    | soft6softer1 Beta        |
| 25                    | soft2softer3             | 3C                    | soft6softer1 Gamma       |
| 26                    | soft3softer1 Alpha       | 3D                    | Time Not In Use          |
| 27                    | soft3softer1 Beta        |                       |                          |
| 28                    | soft3softer1 Gamma       |                       |                          |
| 29                    | soft3softer2 Alpha Beta  |                       |                          |
| 2A                    | soft3softer2 Beta Gamma  |                       |                          |
| 2B                    | soft3softer2 Gamma Alpha |                       |                          |
| 2C                    | soft3softer3             |                       |                          |

# Nortel BTSC MO Events

Each event counter is maintained during the 15-minute automatic logging period.

| Event Report Name   | Type<br>Event Report | Seq.<br>Number | Description  |
|---------------------|----------------------|----------------|--|
| BTSCPerformanceData | PerformanceData      | 0x000?<br>0?   | Includes as parameters all attributes with P access documented in the attribute table for this MO. |

# FA MO Events

Each event counter is maintained during the 15-minute automatic logging period.

| Event Report Name | Type<br>Event Report | Seq.<br>Number | Description  |
|-------------------|----------------------|----------------|--|
| FAPerformanceData | PerformanceData      | 0x000?<br>0?   | Includes as parameters all attributes with P access documented in the attribute table for this MO. |

# Nortel BTSC MO Report Example

XYZ 19971120 BTSC MO Report

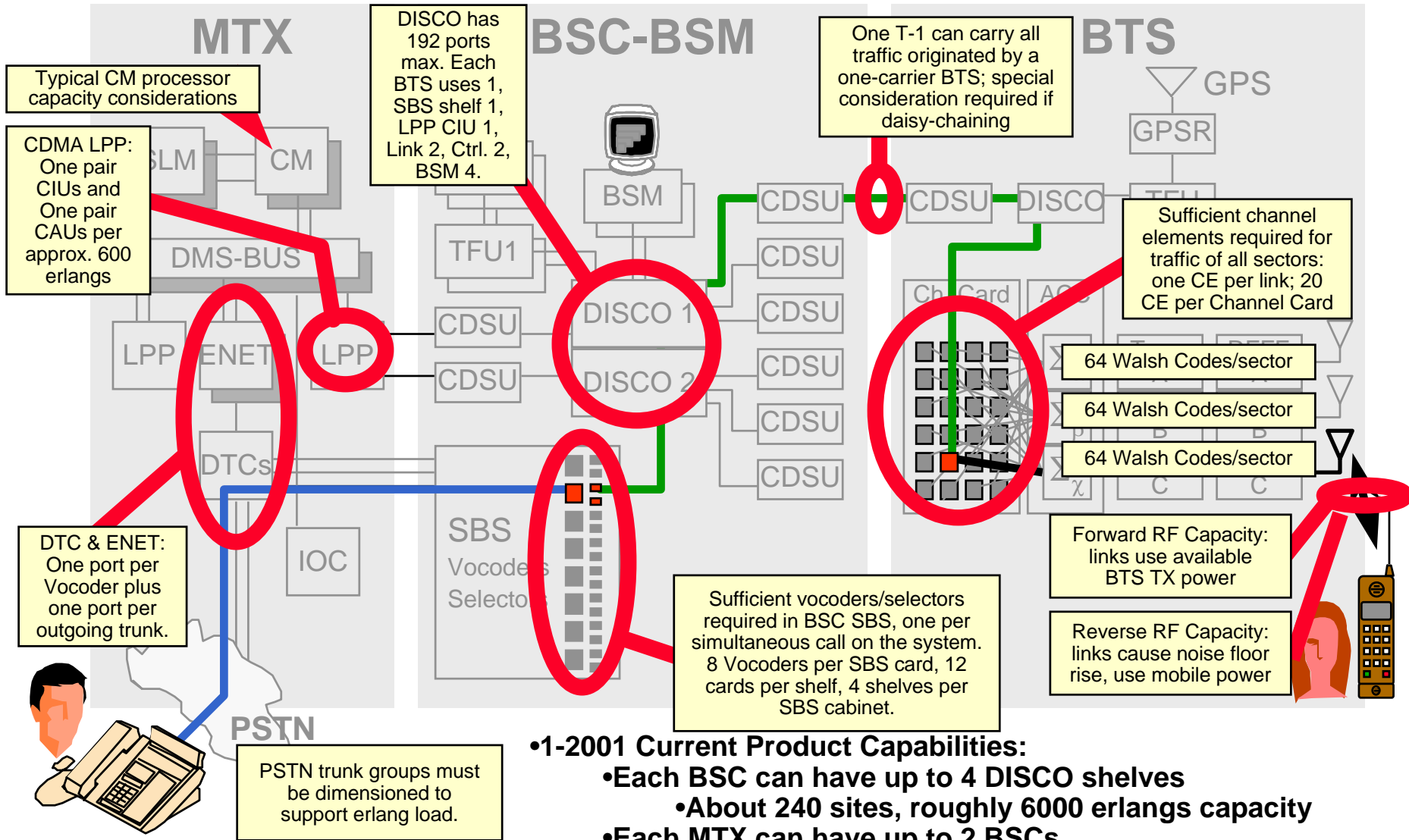
| BTS | Start Date/Time -<br>End Date/Time | OBlock<br>No TCE | OBlock<br>No Fwd | OBlock<br>No Rev | HBlock<br>No TCE | HBlock<br>No Fwd | HBlock<br>No Rev | Succ<br>Orig | Succ<br>Handof |
|-----|------------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|--------------|----------------|
| 1   | 1997/11/20 01:30:00-02:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 3            | 5              |
| 1   | 1997/11/20 12:00:00-12:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 46           | 314            |
| 1   | 1997/11/20 12:30:00-13:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 76           | 470            |
| 1   | 1997/11/20 13:00:00-13:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 45           | 414            |
| 1   | 1997/11/20 13:30:00-14:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 55           | 375            |
| 1   | 1997/11/20 14:00:00-14:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 50           | 525            |
| 1   | 1997/11/20 14:30:00-15:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 72           | 433            |
| 1   | 1997/11/20 15:00:00-15:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 66           | 412            |
| 1   | 1997/11/20 15:30:00-16:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 53           | 323            |
| 1   | 1997/11/20 16:00:00-16:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 63           | 342            |
| 1   | 1997/11/20 16:30:00-17:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 51           | 331            |
| 1   | 1997/11/20 17:00:00-17:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 39           | 323            |
| 1   | 1997/11/20 17:30:00-18:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 51           | 310            |
| 1   | 1997/11/20 18:00:00-18:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 45           | 237            |
| 1   | 1997/11/20 18:30:00-19:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 31           | 299            |
| 1   | 1997/11/20 19:00:00-19:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 37           | 282            |
| 1   | 1997/11/20 19:30:00-20:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 19           | 143            |
| 1   | 1997/11/20 20:00:00-20:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 18           | 96             |
| 1   | 1997/11/20 20:30:00-21:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 33           | 192            |
| 1   | 1997/11/20 21:00:00-21:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 25           | 226            |
| 1   | 1997/11/20 21:30:00-22:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 15           | 235            |
| 1   | 1997/11/20 22:00:00-22:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 15           | 216            |
| 1   | 1997/11/20 22:30:00-23:00:00       | 0                | 0                | 0                | 0                | 0                | 0                | 9            | 162            |
| 1   | 1997/11/20 23:00:00-23:30:00       | 0                | 0                | 0                | 0                | 0                | 0                | 3            | 40             |
|     | Totals for BTS 1                   | 0                | 0                | 0                | 0                | 0                | 0                | 1235         | 8895           |

# Nortel FAMO Report Example

XYZ 19971120 FA MO Report

| BTS | Start Date/Time -<br>End Date/Time | MOU<br>CE | MOU<br>Traffic | CE/<br>User | MOU<br>Alpha | MOU<br>Beta | MOU<br>Gamma | %Soft<br>HO | Max<br>TCE |
|-----|------------------------------------|-----------|----------------|-------------|--------------|-------------|--------------|-------------|------------|
| 1   | 1997/11/20 07:00:00-07:30:00       | 41.99     | 33.35          | 1.26        | 11.77        | 4.62        | 16.96        | 20.58       | 15         |
| 1   | 1997/11/20 07:00:00-07:30:00       | 73.06     | 46.22          | 1.58        | 17.72        | 14.10       | 14.39        | 36.75       | 15         |
| 1   | 1997/11/20 08:00:00-08:30:00       | 109.87    | 66.05          | 1.66        | 24.78        | 20.21       | 21.06        | 39.88       | 15         |
| 1   | 1997/11/20 10:00:00-10:30:00       | 153.79    | 89.81          | 1.71        | 41.85        | 32.19       | 15.77        | 41.60       | 15         |
| 1   | 1997/11/20 10:30:00-11:00:00       | 181.09    | 102.19         | 1.77        | 43.60        | 28.22       | 30.38        | 43.57       | 15         |
| 1   | 1997/11/20 11:00:00-11:30:00       | 152.59    | 84.73          | 1.80        | 37.61        | 18.51       | 28.61        | 44.47       | 15         |
| 1   | 1997/11/20 11:30:00-12:00:00       | 143.70    | 89.16          | 1.61        | 39.66        | 24.78       | 24.72        | 37.95       | 15         |
| 1   | 1997/11/20 12:00:00-12:30:00       | 156.58    | 89.52          | 1.75        | 25.51        | 21.91       | 42.10        | 42.83       | 15         |
| 1   | 1997/11/20 12:30:00-13:00:00       | 165.54    | 89.97          | 1.84        | 44.41        | 22.89       | 22.67        | 45.65       | 15         |
| 1   | 1997/11/20 13:00:00-13:30:00       | 170.36    | 99.19          | 1.72        | 52.81        | 24.58       | 21.79        | 41.78       | 15         |
| 1   | 1997/11/20 13:30:00-14:00:00       | 145.34    | 93.71          | 1.55        | 41.88        | 24.05       | 27.77        | 35.53       | 15         |
| 1   | 1997/11/20 14:00:00-14:30:00       | 189.61    | 121.49         | 1.56        | 52.43        | 30.99       | 38.06        | 35.93       | 15         |
| 1   | 1997/11/20 14:30:00-15:00:00       | 153.65    | 108.08         | 1.42        | 47.58        | 37.52       | 22.99        | 29.65       | 15         |
| 1   | 1997/11/20 15:00:00-15:30:00       | 165.08    | 106.66         | 1.55        | 49.00        | 29.69       | 27.97        | 35.39       | 15         |
| 1   | 1997/11/20 15:30:00-16:00:00       | 159.27    | 94.72          | 1.68        | 42.04        | 28.43       | 24.25        | 40.53       | 15         |
| 1   | 1997/11/20 16:00:00-16:30:00       | 172.52    | 114.62         | 1.51        | 56.57        | 28.50       | 29.55        | 33.56       | 15         |
| 1   | 1997/11/20 16:30:00-17:00:00       | 156.83    | 105.46         | 1.49        | 53.29        | 30.38       | 21.80        | 32.76       | 15         |
| 1   | 1997/11/20 17:00:00-17:30:00       | 129.13    | 82.52          | 1.56        | 31.50        | 24.28       | 26.73        | 36.10       | 15         |
| 1   | 1997/11/20 17:30:00-18:00:00       | 134.80    | 81.76          | 1.65        | 35.80        | 30.20       | 15.77        | 39.35       | 15         |
| 1   | 1997/11/20 18:00:00-18:30:00       | 96.91     | 60.49          | 1.60        | 27.80        | 15.38       | 17.31        | 37.58       | 15         |
| 1   | 1997/11/20 18:30:00-19:00:00       | 124.25    | 73.62          | 1.69        | 22.37        | 30.93       | 20.33        | 40.75       | 15         |
| 1   | 1997/11/20 19:00:00-19:30:00       | 75.50     | 41.14          | 1.83        | 18.03        | 14.88       | 8.24         | 45.50       | 15         |
| 1   | 1997/11/20 19:30:00-20:00:00       | 40.58     | 23.56          | 1.72        | 12.50        | 5.72        | 5.33         | 41.95       | 15         |
| 1   | 1997/11/20 20:00:00-20:30:00       | 51.14     | 29.81          | 1.72        | 13.26        | 10.37       | 6.19         | 41.71       | 15         |
| 1   | 1997/11/20 20:30:00-21:00:00       | 102.45    | 55.26          | 1.85        | 16.36        | 18.49       | 20.41        | 46.07       | 15         |
| 1   | 1997/11/20 21:00:00-21:30:00       | 108.48    | 74.86          | 1.45        | 28.32        | 17.26       | 29.27        | 30.99       | 15         |
| 1   | 1997/11/20 21:30:00-22:00:00       | 109.92    | 68.50          | 1.60        | 26.53        | 19.22       | 22.75        | 37.68       | 15         |
| 1   | 1997/11/20 22:00:00-22:30:00       | 86.58     | 59.36          | 1.46        | 26.09        | 15.11       | 18.15        | 31.45       | 15         |
| 1   | 1997/11/20 22:30:00-23:00:00       | 94.96     | 63.48          | 1.50        | 27.73        | 20.85       | 14.90        | 33.15       | 15         |
| 1   | 1997/11/20 23:00:00-23:30:00       | 28.07     | 20.76          | 1.35        | 9.06         | 8.14        | 3.55         | 26.04       | 15         |
|     | Totals for BTS 1                   | 3690.90   | 2280.64        | 1.62        | 980.80       | 655.61      | 644.22       | 38.21       | 15         |

# Nortel Operational Capacity Considerations

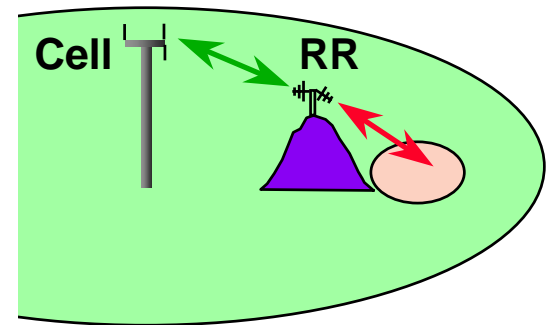


# Section 7C

## Reradiators

# Wireless Reradiators

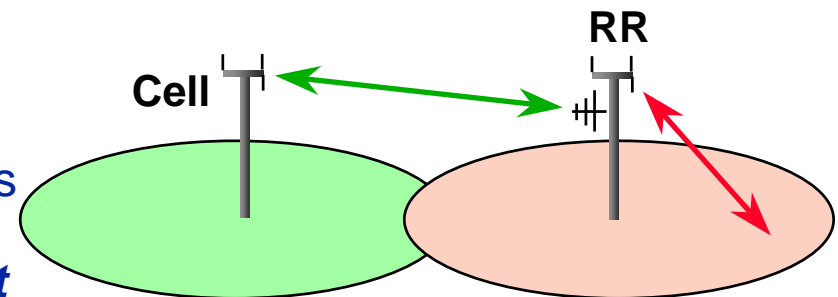
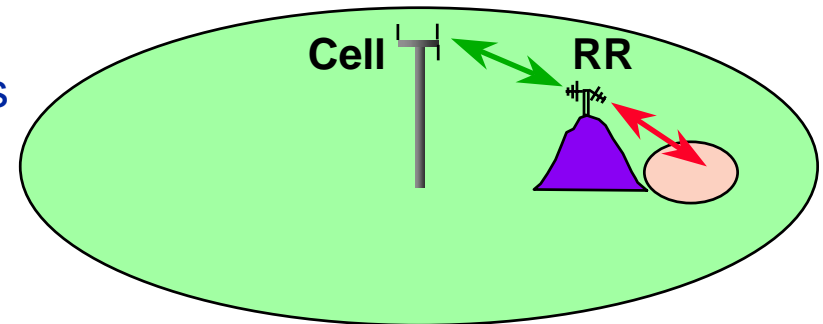
- **Reradiators** (also called “**boosters**”, “**repeaters**”, “**cell enhancers**”) are amplifying devices intended to add coverage to a cell site
- Reradiators are **transparent** to the host Wireless system
  - A reradiator amplifies RF signals in both directions, uplink and downlink
  - The system does not control reradiators and has no knowledge of anything they do to the signals they amplify, on either uplink or downlink
- Careful attention is required when using reradiators to solve coverage problems
  - to achieve the desired coverage improvement
  - to avoid creating interference
  - to ensure the active search window is large enough to accommodate both donor signal and reradiator signal as seen by mobiles



**Reradiators are a “crutch” with definite application restrictions. Many operators prefer not to use re-radiators at all. However, reradiators are a cost-effective solution for some problems.**

# Wireless Reradiators

- Two types of **Reradiators** commonly are applied to solve two types of situations:
  - “**filling in**” **holes** within the coverage area of a cell site -- valleys and other obstructed locations, convention centers, etc.
    - **Low-Power broadband** reradiators are used for this purpose (AMPS, TDMA, GSM, CDMA)
  - **expanding the service area** of a cell to large areas beyond its natural coverage area
    - **High-Power, channelized** frequency-translating reradiators are used for this purpose
    - Only used in AMPS, TDMA; **not currently feasible for CDMA**

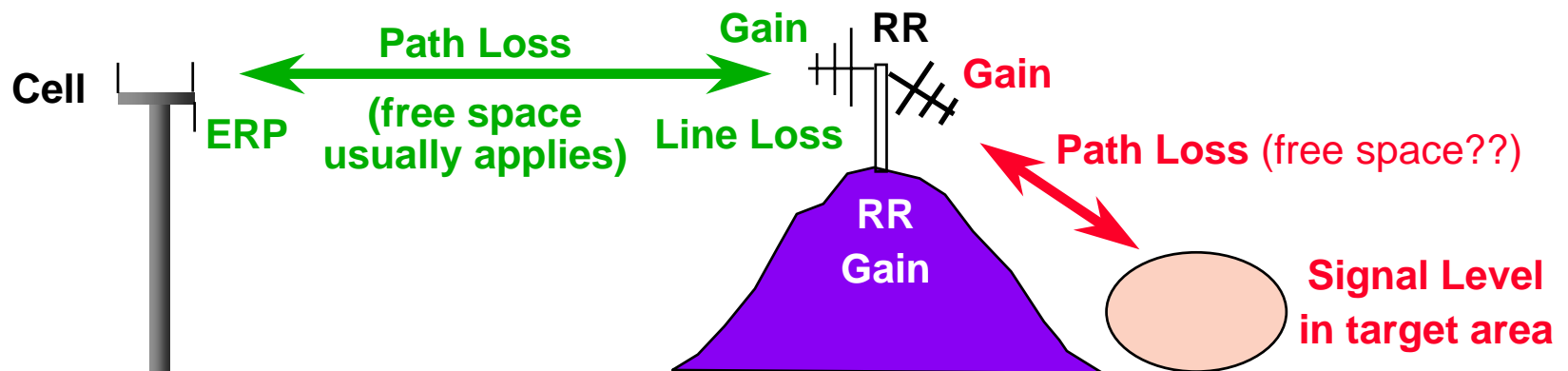




# Wireless Reradiators

## Propagation Path Loss Considerations

- To solve a coverage problem using a reradiator, path loss and link budget must be considered
  - how much **reradiator gain** is required?
  - how much **reradiator output power** is required?
  - what type of **antennas** would be best?
  - how much antenna **isolation** is needed?
  - how big will the reradiator **footprint** be?
  - **how far** can the reradiator be from the cell?
  - will the reradiator **interfere** with the cell in other areas?
  - What is the propagation delay through the reradiator, in chips?
  - Will search windows need to be adjusted for compensation?



# Wireless Reradiators

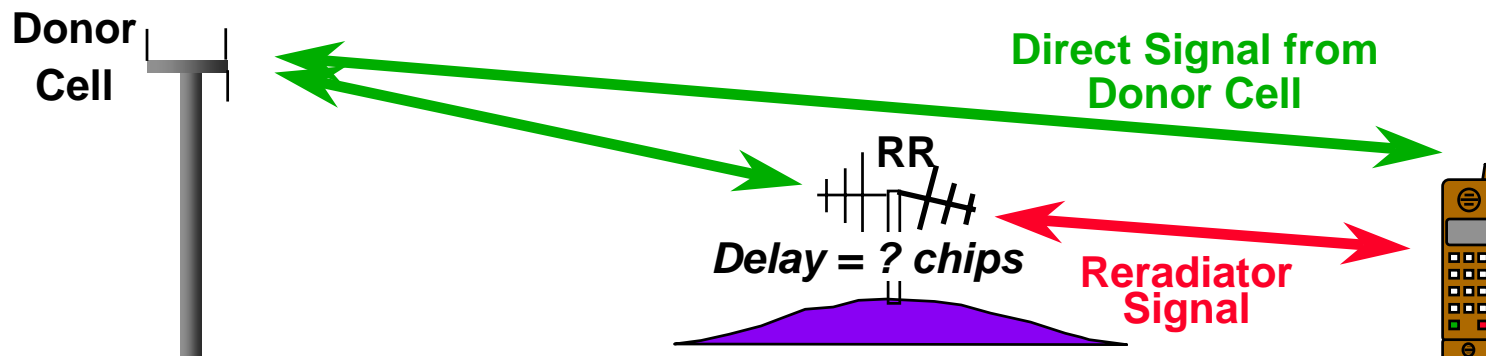
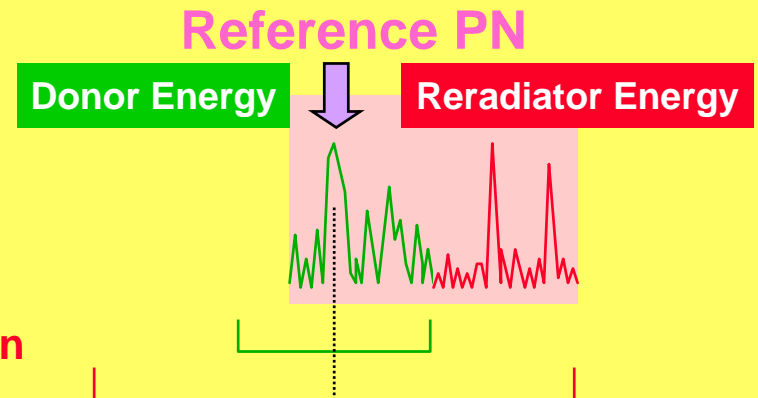
## Search Window Considerations

- A reradiator introduces additional PN delay
  - typically 5 to 30 chips
  - the energy seen by the mobile and by the base station is spread out over a wider range of delays

### DON'T FORGET THE WINDOWS!

Search Windows must be widened by approximately 2 x reradiator delay to ensure capture of both donor and rerad energy by mobile and base station.

- **Srch\_Win\_A, Srch\_Win\_R, Srch\_Win\_N**
- **Base station Acquisition & Demodulation search windows**

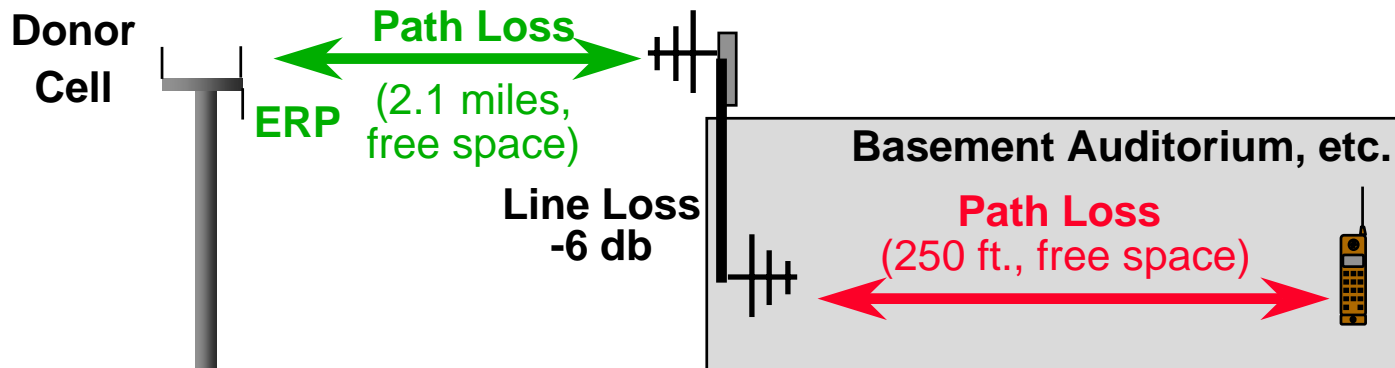


# Passive Wireless Reradiators

## Typical Link Budget

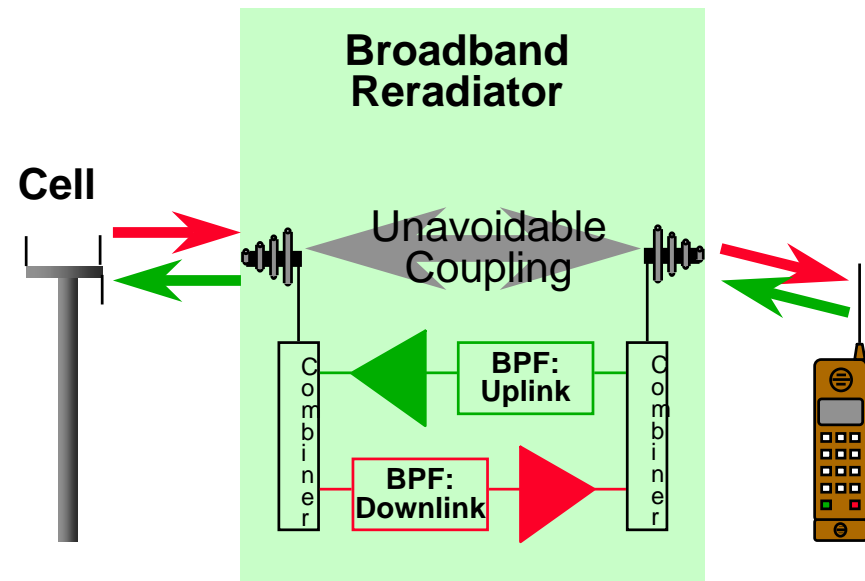
- In a few special cases, it is possible to reradiate useful Wireless coverage without any amplifiers involved!
- Link budget is marginal
  - donor cell must be nearby
  - high-gain antenna required toward donor cell
  - distance from RR to user must be small
    - $\cong$ 100 feet feasible w/omni antenna
    - $\cong$ 500 feet w/directional antenna

| Passive Reradiator Link Budget Example |      |     |
|--|------|-----|
| Donor cell EIRP                        | +52  | dBm |
| Path Loss Donor<>RR                    | -102 | dB  |
| RR Donor Ant. Gain                     | +22  | dBi |
| Signal Level into Line                 | -28  | dBm |
| RR Line Loss                           | -6   | dB  |
| RR Serving Ant. Gain                   | +12  | dBi |
| Path Loss RR<>User                     | -69  | dB  |
| Signal Level @ User                    | -91  | dBm |



# Broadband Low-Power Wireless Reradiators

- Used mainly for filling small “holes” in coverage area of a cell
- Input and output on same frequency
  - usable gain: must be less than isolation between antennas, or oscillation occurs
  - this gain restriction seriously limits available coverage
  - Typically achievable isolations: 70-95 dB
  - Good point: every channel in donor cell is re-radiated

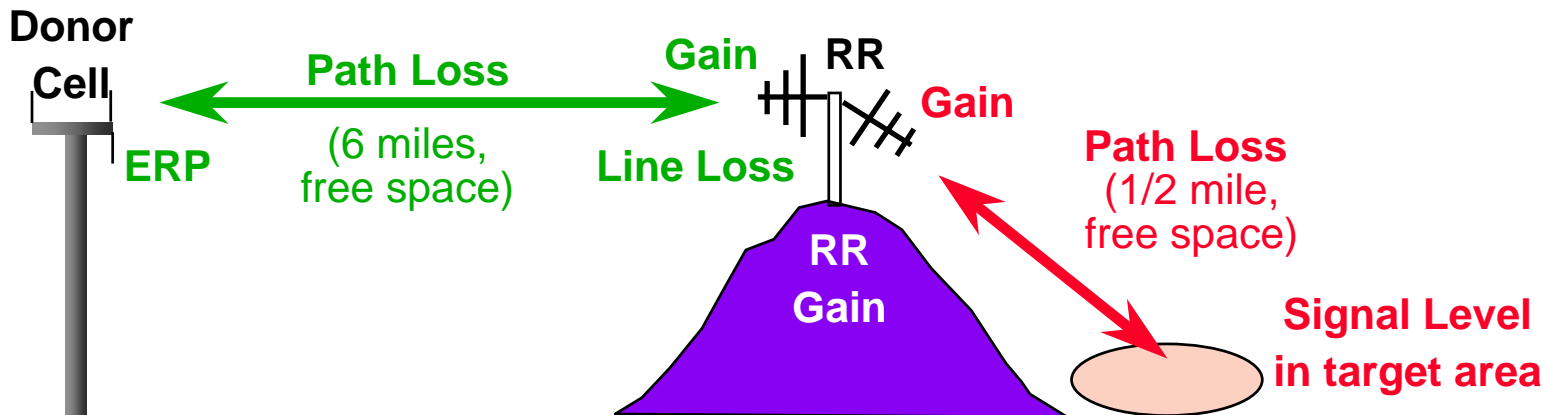


# Broadband Low-Power Wireless Reradiators

## Typical Link Budget

- Broadband low-power reradiators can deliver useful signal levels over footprints up to roughly 1 mile using nearby donor cells
- Link budget is usually very “tight”
  - paths can’t be seriously obstructed
  - antenna isolation must be at least 10 db more than desired RR gain
  - can’t overdrive reradiator 3rd. order IM

| Broadband Reradiator Link Budget Example |       |     |
|--|-------|-----|
| Donor cell EIRP                          | +52   | dBm |
| Path Loss Donor<>RR                      | -111  | dB  |
| RR Donor Ant. Gain                       | +12   | dBi |
| RR Line Loss                             | -3    | dB  |
| Signal Level into RR                     | -50   | dBm |
| RR Gain                                  | +50   | dB  |
| RR Power Output                          | +0    | dBm |
| RR Line Loss                             | -3    | dB  |
| RR Serving Ant. Gain                     | +12   | dBi |
| Path Loss RR<>User                       | -89.4 | dB  |
| Signal Level @ User                      | -80.4 | dBm |



# Other Reradiator Issues

- **Amplification of Undesired Signals**
  - The reradiator is a broadband device capable of amplifying other signals near the intended CDMA carrier, both on uplink and downlink. Will these signals capture unwanted traffic, cause unwanted interference, or overdrive CDMA handsets or the base station?
- **Linearity**
  - CDMA reradiators must be carefully adjusted to ensure they are not overdriven. Overdriving would produce clipping or other nonlinearities, resulting in code interference
- **Traffic Capacity**
  - Re-radiators may introduce enough new traffic to create overloads in the donor cell
- **Alarms**
  - Separate arrangements must be made for integrating alarms and surveillance reports from reradiators into the system