



**Reverse Link Capacity Measurement  
and Capacity Improvement by  
Mobile Transmit Diversity**

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# Agenda

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- Introduction
- Reverse Link Capacity and the noise Rise Over Thermal noise (ROT)
- Capacity Measurement
  - Measurement for Single Cell
  - Measurement for a Cluster of Multiple Sectors
- RL Capacity Improvement by MTD technology
- Field Trials on Capacity Measurement
- Summary

# Company overview

- Established in 2000, Magnolia is a fabless semiconductor venture backed company building Mobile Transmit Diversity solution for the CDMA and IMTS industries
- Magnolia is the only company to offer a non intrusive, network agnostic approach:
  - Improving range, capacity, data rate
  - That without sacrificing handset battery life
- HSUPA and REV A, WiMAX are 6-10 dB short on uplink link budget
- Current solution based on a stand alone chip, next version will be an integrated solution, driving extra BOM to a \$1 range



# Different Needs for Different Operators

Technology	Value Proposition	Operators
CDMA 2000	<ul style="list-style-type: none"><li>a) Voice Capacity, quality, churn and equipment warranty</li><li>b) Migration from EVDO Rev 0 to EVDO Rev A</li></ul>	Sprint, Verizon, Alltel, China Unicom etc
UMTS	<ul style="list-style-type: none"><li>a) Voice Capacity, quality, churn and equipment warranty</li><li>b) Co-location of new deployments</li><li>c) Migration from UMTS to HSDPA/UPA</li></ul>	Cingular, Vodaphone, O2, Orange, Hutchinson etc

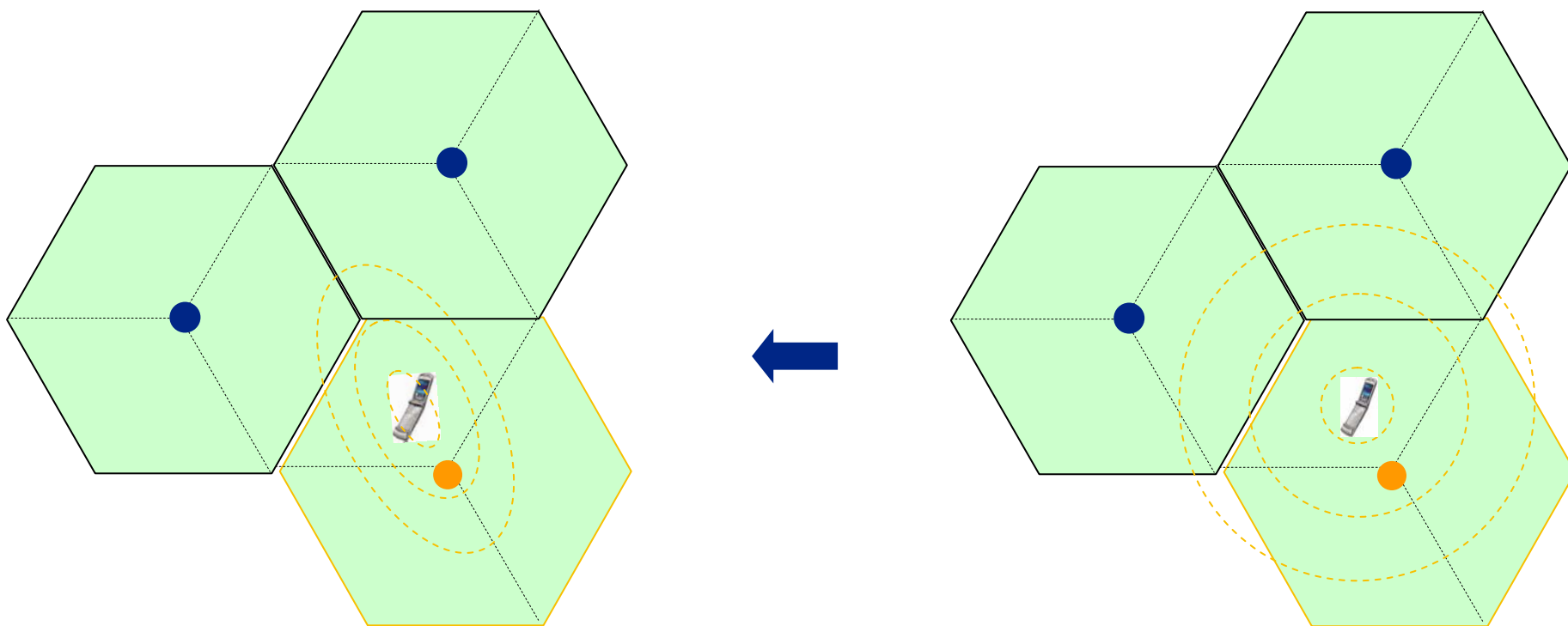
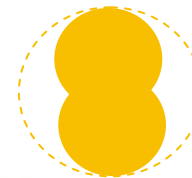
# Link imbalance



Characteristic	REV O CDMA	REV A CDMA
Uplink Data Rate*	153Kbps	1.8Mbps
Modulation Type	BPSK	8-PSK
Additional Margin	n/a	+11dB

Characteristic	UMTS (Rel 99)	HSUPA (Rel 6)
Uplink Data Rate*	384Kbps	5.76 Mbps
Modulation Type	BPSK	QPSK
Additional Margin	n/a	+12dB

# Capacity



# Pole Capacity and ROT

- Reverse Link capacity for a **sector** can be defined as the (pole) maximum users ( $N_{max}$ ) can be support in the sector from noise aspect.
- Cell loading can be defined as  $\mu = N/N_{max}$
- Noise rise ( $\tau$ ) is the total received power (**RSSI**) over the thermal noise at the cell site.
- They can be associated,

$$\tau = \frac{1}{1 - \mu} \dots\dots\dots (1)$$

$N$  is the number of active users.

# Pole Capacity and ROT

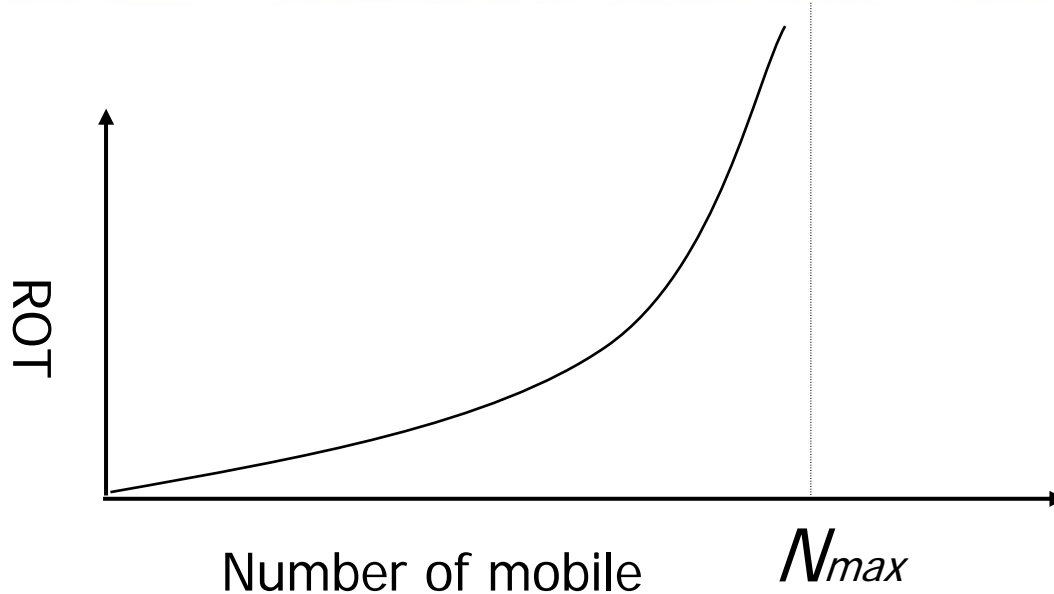
- $\tau$  and  $\tau'$  are the measured noise rises for a sector with the fixed number of mobiles operating without and with diversity antenna.
- The capacity improvement for the sector can then be presented by the new pole capacity ( $N_{max\_DIV}$ ) and the original pole capacity ( $N_{max}$ ),

$$\frac{N_{max\_DIV} - N_{max}}{N_{max}} = \frac{\tau - \tau'}{\tau (\tau' - 1)} \dots \dots \dots (2)$$

# Capacity for a Single Cell (Sector)

- ROT ( $\tau$ ) is used in the CDMA base stations for the overload control. Hence, it is usually available to be collected.
- In a single cell (sector), we may increase the phone calls for test mobiles until the cell reach the high level overload control and also monitor the ROT values. We can extrapolate the pole capacity ( $N_{max}$ ) for a single sector by the monotonically increased ROT reaching the very large value (or infinity).
- However, the capacity of single cell is hardly affected by the MTD mobiles. The diversity gain of MTD mobile presents the reduction of mobile transmit power and hence reduces other cell interference. It only marginally reduces the received power at base station by fading mitigation.

# Capacity for a Single Cell (Sector)

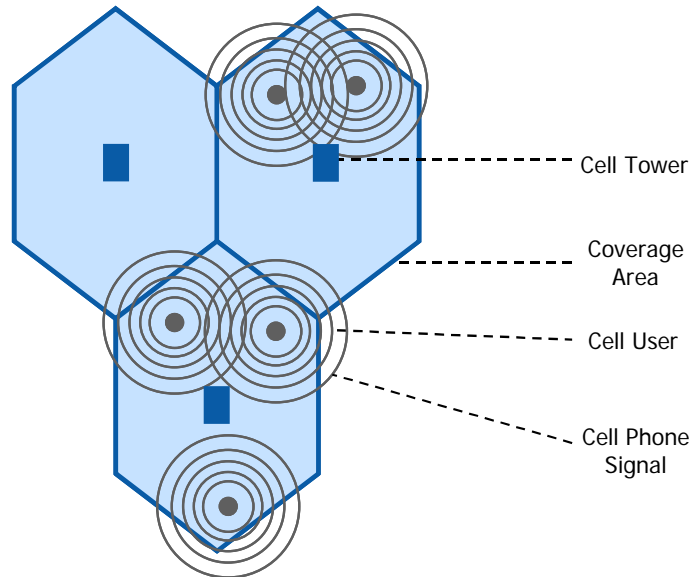


Hence, from the ROT curves for a single cell, we may not be able to distinguish between the regular mobiles and the MTD mobiles.

The capacity improvement (or ROT reduction) by MTD mobiles can be observed completely only through a cluster of multiple cells (sectors).

# Capacity for Multiple Sectors

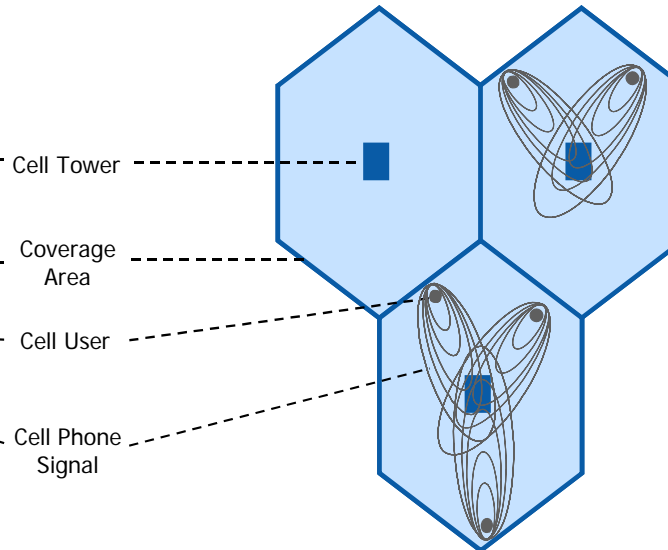
Handsets **without** Magnolia's DiversityPlus™ Solution



**Figure 1: (Without DiversityPlus)**

- Handset signals create interference and inefficiencies on the network
- Signals transmitted from handsets located far from the base station are forced to increase power output in order to ensure that their signals will reach the tower

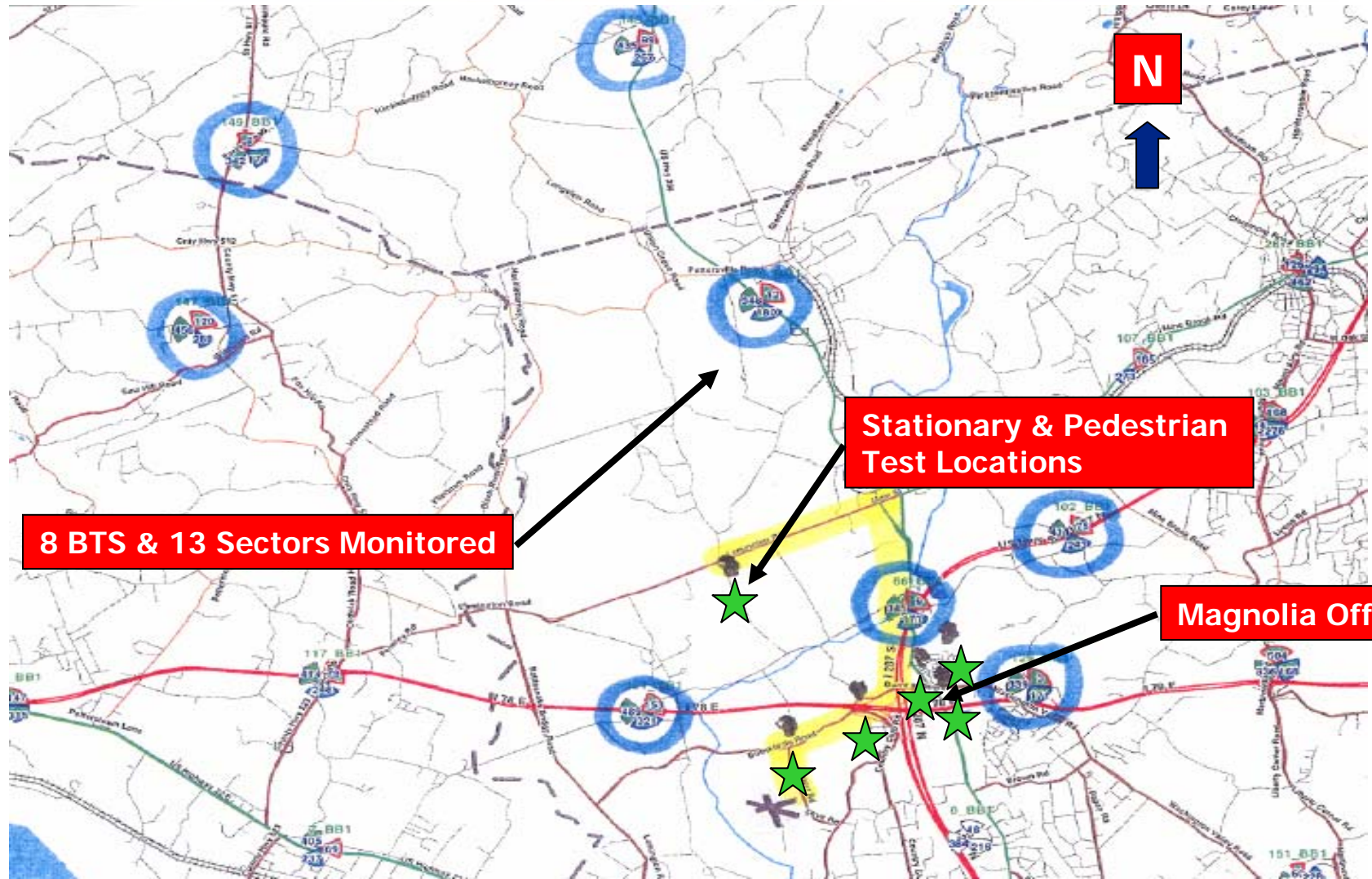
Handsets **with** Magnolia's DiversityPlus™ Solution



**Figure 2: (with DiversityPlus)**

- Magnolia's transmit diversity solution enables more efficient sharing of network capacity by both directing and extending the handset transmissions toward the tower
- The solution reduces interference and decreases power requirements for handsets at the edge of the coverage area

# Capacity Meas. for Multiple Sectors



# Capacity Meas. for Multiple Sectors

- Perform simultaneous testing of multiple transmit diversity-equipped handsets in an operational network
- Measure observed ROT for all cell sectors in the vicinity of the test region
- Conduct testing in two modes: (1) conventional single-antenna transmission, and (2) two-antenna transmit diversity transmission
- Testing divided into “cycles”, each comprised of two test sessions:
  - 15 minute session (data collection) each for Non-Diversity & Diversity Mode

# Capacity Meas. for Multiple Sectors

- Testing may be conducted for three types of user mobility
  - Static: all devices stationary
  - Pedestrian: all devices moving at speed <5 mph, operated from vehicle
  - Drive: all devices moving at speed between 30 and 50 mph

Example

Cycle	Session	Diversity Status	Start Time	End Time
Static	1	Non-Diversity	12:00 AM	12:15 PM
	2	Diversity	12:15 AM	12:30 AM
Static	1	Non-Diversity	12:30 AM	12:45 AM
	2	Diversity	12:45 AM	1:00 AM
Pedestrian	1	Non-Diversity	1:00 AM	1:15 AM
	2	Diversity	1:15 AM	1:30 AM
Pedestrian	1	Non-Diversity	1:30 AM	1:45 AM
	2	Diversity	1:45 AM	2:00 AM
Vehicular	1	Diversity	2:15 AM	2:30 AM
	2	Non-Diversity	2:30 AM	2:45 AM
Vehicular	1	Diversity	2:45 AM	3:00 AM
	2	Non-Diversity	3:00 AM	3:15 AM
Baseline			3:15 AM	4:00 AM

# Capacity Meas. for Multiple Sectors

- RSSI Measurements

The RSSI collection is synchronized with the antenna configuration (non-diversity and diversity)

- Noise Floor Measurement,  $N_o$

- Based on RSSI measurements made during “baseline” sessions when all the mobiles power off
- The minimum observed RSSI value for each sector used as the  $N_o$  estimate

- ROT Measurements: computed as  $\text{RSSI} / N_o$

# Capacity Meas. - Data Analysis

- Average ROT, per Test Period, per Sector
  - For each 15-minute test session and each sector, the RSSI measurements is averaged for the antenna configuration. We will discard the data for the beginning minute and the ending minute of each session to ensure the synchronization
  - An average RSSI computed for each test antenna configuration in each session and for each sector
  - $N_o$  estimated for each sector as the smallest observed RSSI value obtained during all baseline testing
  - The average ROT computed for each test session and each sector as the ratio of the average RSSI value to  $N_o$

# Capacity Meas. - Data Analysis

- Average ROT, per Test Period, per Sector
- The averaged ROT are calculated for each session and for each sector.
- Use the Equation (2), we obtain the capacity improvement for each sector and for each test period.
- The overall capacity gain for the cluster of multiple sectors is the capacity gains averaged for all the sectors and test periods except of the sector with average ROT (non-diversity mode) less than 0.25 dB. The uncertainty of the ROT measurements is around 0.25 dB.

# Field Trials on Capacity Field Trial

Date	Host	Test Network	Location
July 2005	SK Telecom	CDMA2000 1x EV-DO	Greater Seoul Area
December 2005	Sprint	CDMA 2000 1x (voice)	Greater NJ Area
March 2006	Sprint	CDMA 2000 1x (voice)	Greater NJ Area

# Field Trial on SKT Network



- More than 40 people involved with 20 man-month of effort
- 6 Test Vehicles involved at times

# OEM Handset Programs Sponsored by Carriers



 **Sprint.**  **PANTECH & CURITEL**



**SK Telecom** **SK Teletech**

# 1x Voice Capacity Test on Sprint Network

	Measured Capacity Improvement		
	Cellular (July '05)	PCS (Dec. '06)	PCS (March '06)
Overall	45%	39%	42%

## Summary

- The ROT based capacity measurement has been discussed.
- Single cell (sector) ROT measurement can be used to estimate the capacity of a sector for the “regular” mobiles, but single sector ROT measurement can not show the capacity improvement for the Mobile Transmit Diversity (MTD) mobiles.
- We showed that the ROT measurements for a multiple sectors is able to demonstrate the reverse link capacity improvement by the MTD mobiles.
- The field trials on capacity improvement on the CDMA 20001x and EVDO network by MTD mobiles have been shown. The results show that we can obtain 45% and 42% capacity improvement for a cellular and a PCS network, respectively.

***Thank You...***