DAS Best Practices – IBTUF IX

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Topics-

- **Quality control**
- Managing the customer experience
- Managing the uplink – what is normal?
- Non-invasive PIM testing
- Path balance
- Effects of power scaling

Maintain quality control

- Maintaining tight quality controls during the build process will improve system performance and simplify integration and trouble shooting for the life of the system. Don’t rush.

- PIM - This is a quality test not an operational test
  - Coaxial PIM : -153dBc @ 2x 20W at the eNodeB
  - System PIM : -143dBc @ 2x 20W at the eNodeB

- Labeling is critical - The more detail the better
  - Make sure lines are labeled to your satisfaction

- Return Loss :
  - New Network Standards document ME-RFS-ST-14-0003
  - Targets are based on system components and must be calculated

Operations Support

The full standards document can be located on the Maintenance Engineering Support page

http://mtce.eng.vzwcorp.com/c2/MTCE/content.nsf/lookup.htmlpages/mainframe.html?open

er Advanced Search RFS-ST-14-0003

Title

RF Antenna System VSWR (Return Loss) & PIM Pass-Fail Criteria (ME-RFS-ST-14-0003)

NETWORK STANDARDS			
NUMBER **ME-RFS-ST-14-0003**	DATE ISSUED **04/24/09**	LAST MODIFIED **06/14/14**	REVIEW DATE **06/27/14**
CLASSIFICATION **Company Confidential**	DOCUMENT CUSTODIAN **Scott Semone – MTS RF Maintenance Engineering**		
STATUS **Active**	DOCUMENT TITLE **RF Antenna System VSWR (Return Loss) & PIM Pass-Fail Criteria**		

Minimum Passing Criteria:

- Coaxial System Terminated into a 50Ω Load: $\leq$ -24dB RL (-30dB RL to -35dB RL is typical)
- Coaxial System Return Loss (RL) with Diplex Filters into a 50Ω Load: **Calculated Value** (Calculation Tool)
- System Return Loss (RL) into an Antenna: **Calculated Value** (Calculation Tool)
- Distance to Fault (DTF): Observation only, note & repair impairments due to damaged coaxial cable.

Mandatory PIM Testing:

Coaxial PIM Test: Closed Coaxial System Terminated into a PIM Load: IM3 $\leq$ -153dBc @ 2x20W(43dBm)

System PIM Test: RF System terminated into an Antenna IM3 $\leq$ -143dBc

NOTE: IM3 Values greater than -143dBc require justification of a near proximity external PIM source, and a long-term plan to remove the source or relocate the antenna.

Topics-

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Managing the customer experience

- Customers expect the same service no matter where they are
- A UE should perform the same on a DAS as it does on a macro-cell
- The eNodeB should think it's looking at an air interface
- Excessive noise or link imbalances will either hurt the DAS or the macro network and create unstable customer experience

Air interface – key components

- Noise at the antenna input is kTB (thermal noise)
  - Understand what “normal” looks like
  - Understand equipment reporting differences
    - TRDU, RRH, MRO, MCO, RUL, mRBS, mRRU, etc…
  - Understand what perfect looks like (use loads)
  - Know what “test” ports are really reporting

- The uplink and downlink path losses are the same

- Open loop and closed loop power control algorithms are aiming for the same targets
    - Open Loop targets are based on the difference between the transmitted reference signal information on SIB2 and the UE RSRP
    - Closed loop targets are different between Ericsson (path loss) and Alcatel-Lucent (SINR). Understand how they work

Topics-

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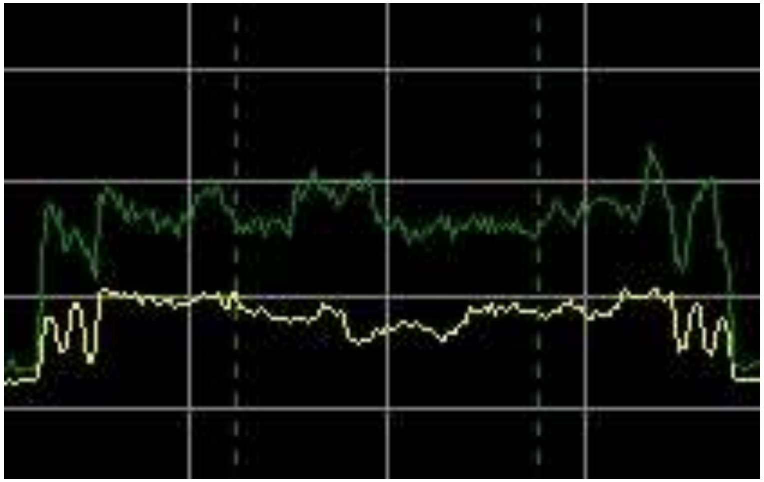
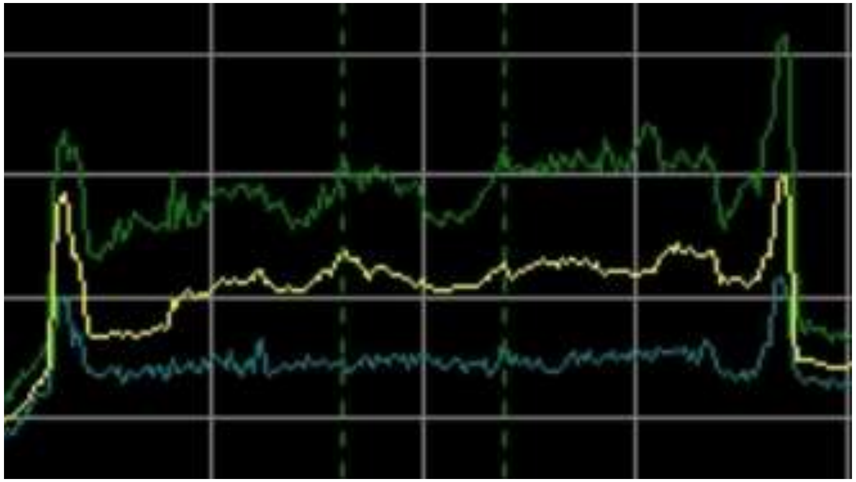
What does “normal” look like?

Typical Ericsson eNodeB Receive



Typical Alcatel-Lucent eNB Receive



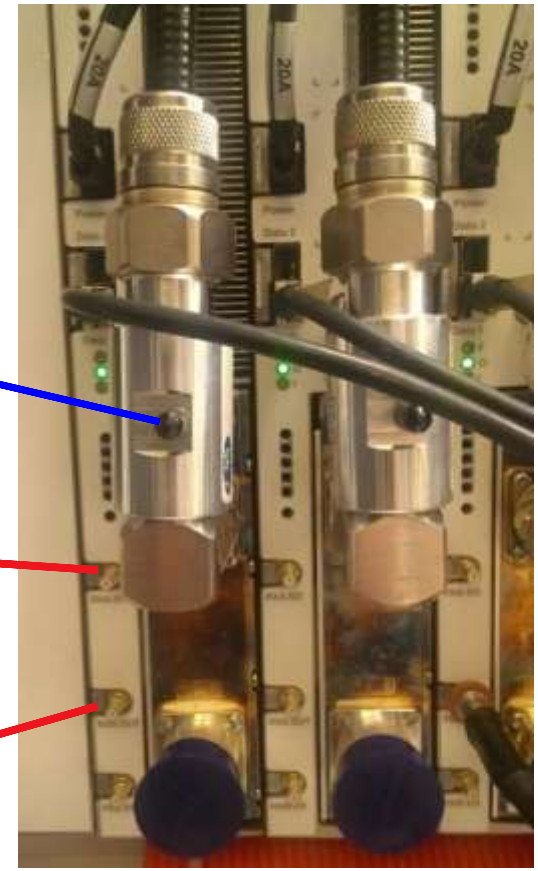
- Power control algorithm differences between ALU and E/// result in very different receive patterns
- Understanding what normal looks like will help in identifying problems
- UE responses to elevated noise are different on Ericsson and Alcatel-Lucent platforms

Ericsson eNodeB

Coupler and Rx Test Ports

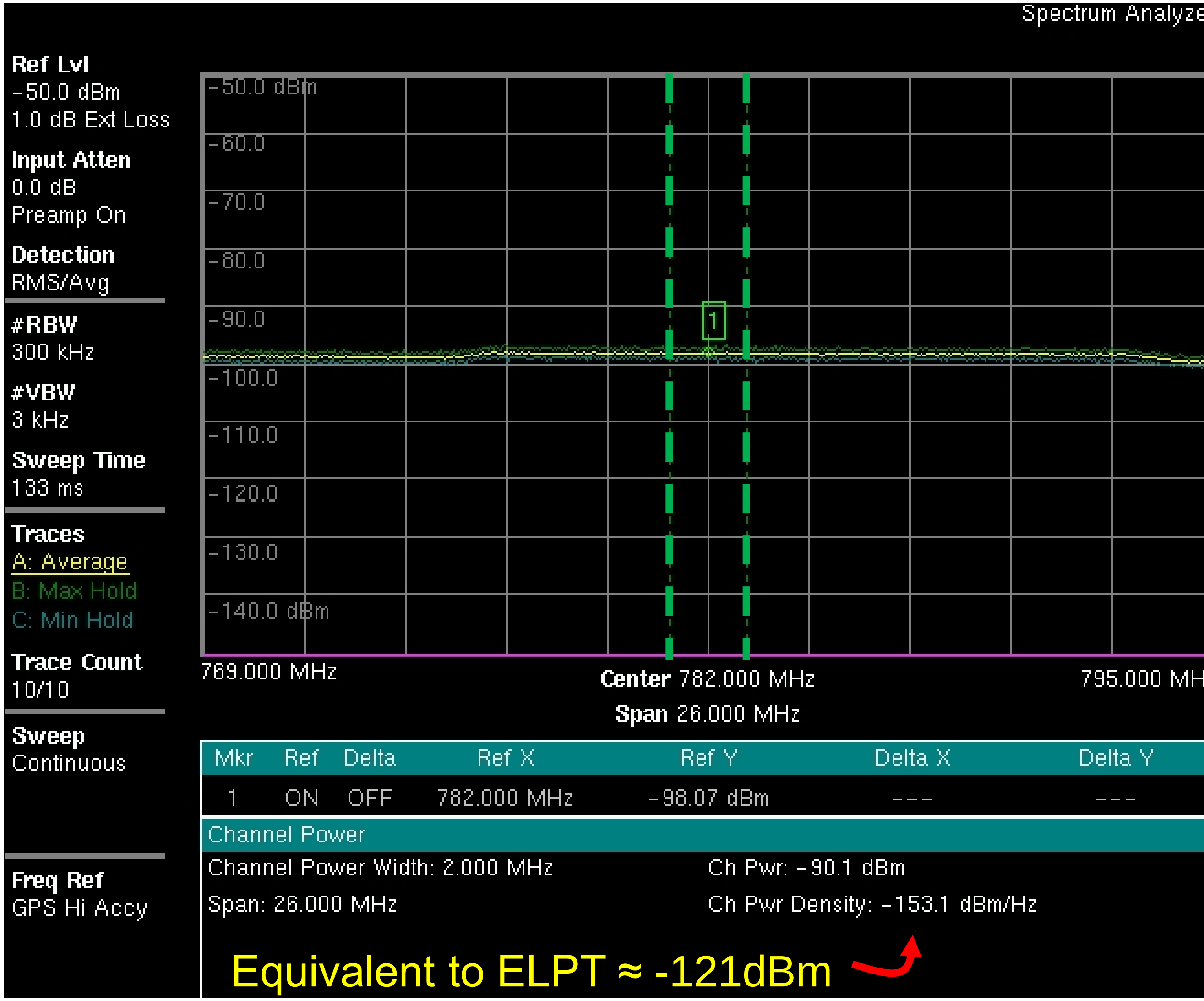
- Remember that the power control reference point should always be the antenna input
- Measurements must include gain/coupling factors

- Coupling is ≈ 41dB
- Tx Coupler is Bi-Directional



Ericsson Perfect Noise Floor (Performance Load on Antenna Input)

- The marker power is defined by the RBW (300kHz)
- The channel power is defined by the ch. power width
- The channel power density is defined per Hertz over the defined width
- Using power density takes away much of the measurement mystery, but not all.



Alcatel-Lucent TRDU

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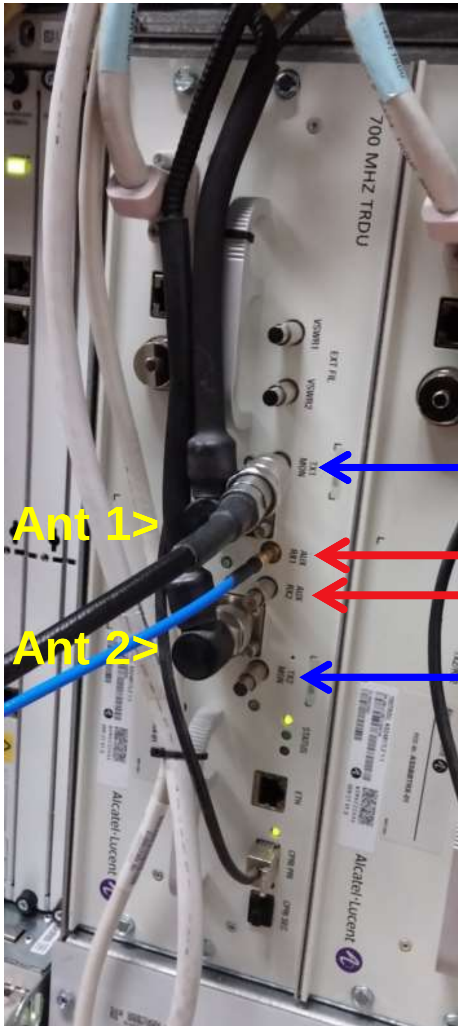

Tx Monitor 1 ≈ 40dB Coupling to Antenna 1 Input

Aux Rx 1 ≈ 25dB Gain from Antenna 1

Aux Rx 2 ≈ 25dB Gain from Antenna 2

Tx Monitor 2 ≈ 40dB Coupling to Antenna 2 Input

ALU TRDU Perfect Noise Floor (Performance Load on Antenna Input)

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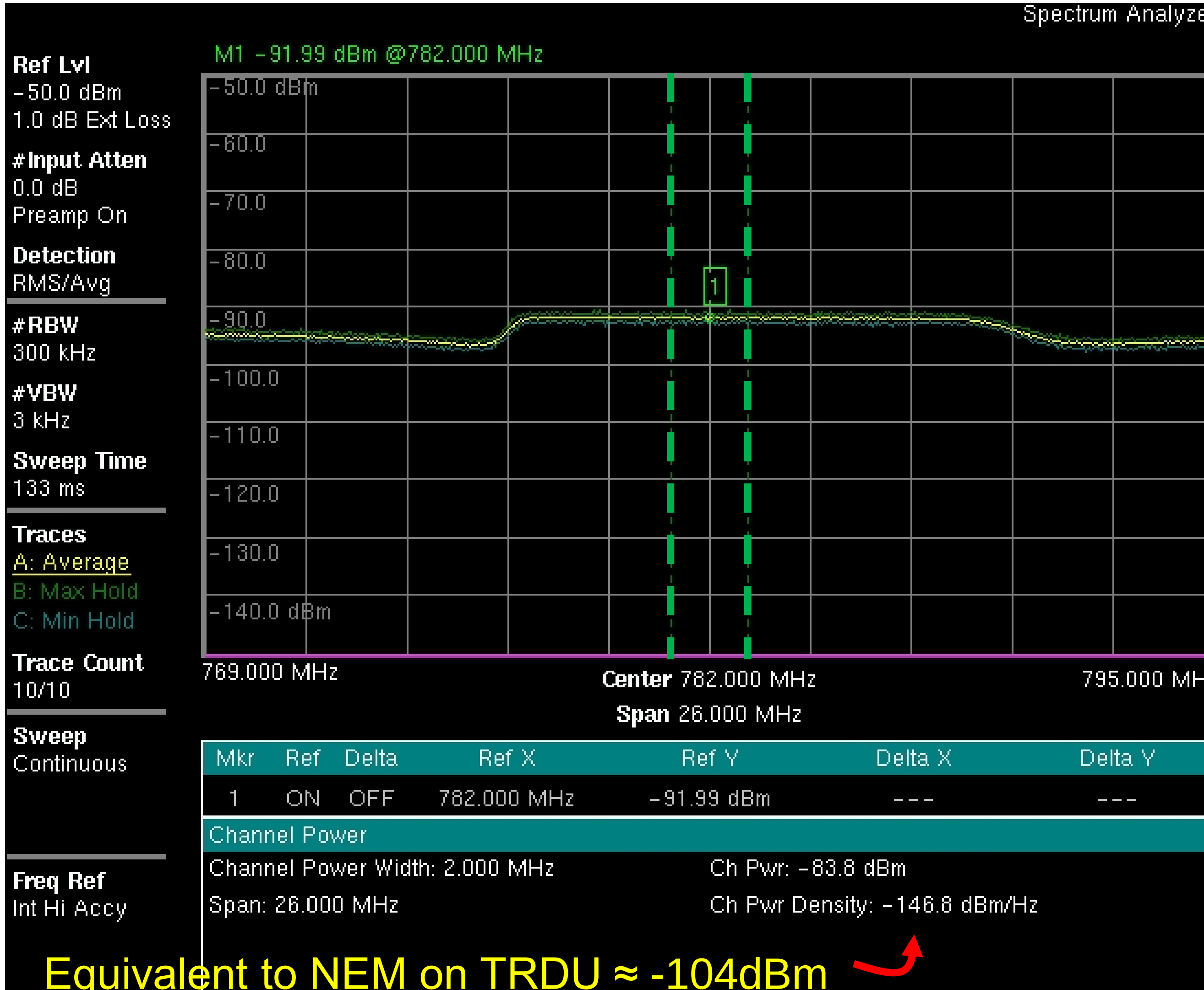


Advantages of couplers…

- Bi-directional couplers provide fast access to the air interface
  - Check downlink power and quality
  - Attach a mag-mount and test the air interface
    - 21dBm RS – 40dB (coupling) - 22dB (path loss at one wavelength) = <u>-41dBm RSRP</u>
    - 21dBm RS – 40dB (coupling) - 42dB (path loss at ten wavelengths) = <u>-61dBm RSRP</u>
  - Small antennas attached to couplers allow for testing in a safe, convenient, controlled environment
    - Load balancing
    - Handoff
    - Power control

What happens if there is excess noise?

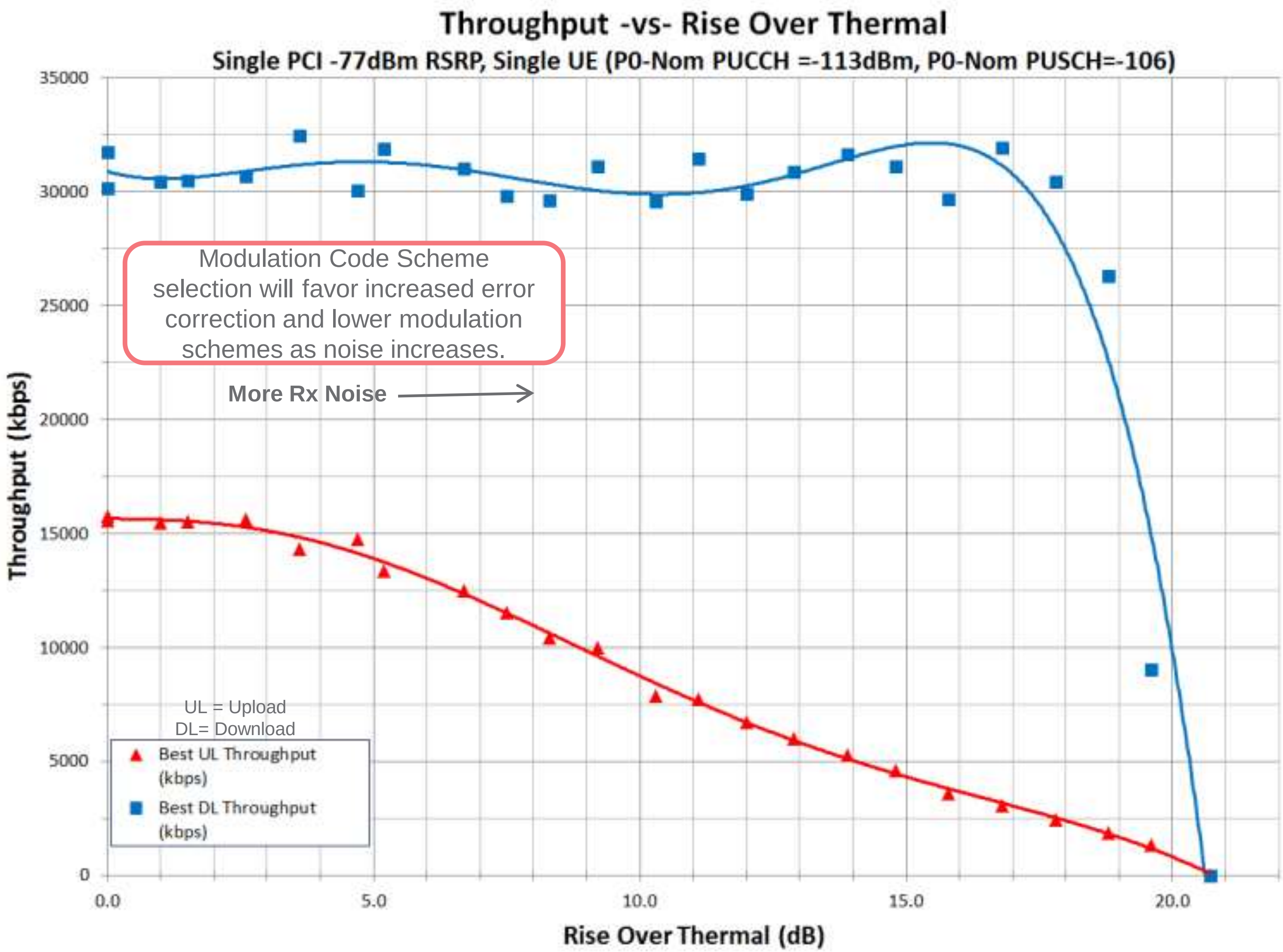
UE Response to interference in ALU

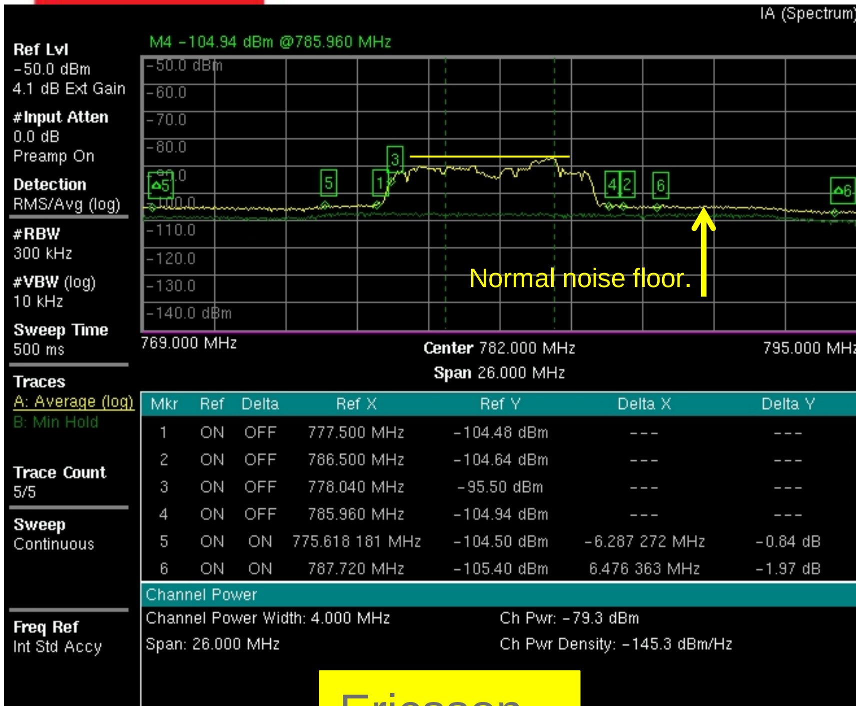
- UE is instructed to increase power to maintain SINR targets
- When the UE becomes power limited
  - Modulation code scheme (MCS) may be reduced to accommodate received SINR limits
  - The number of transmitted physical resource blocks is reduced to maintain SINR with limited power

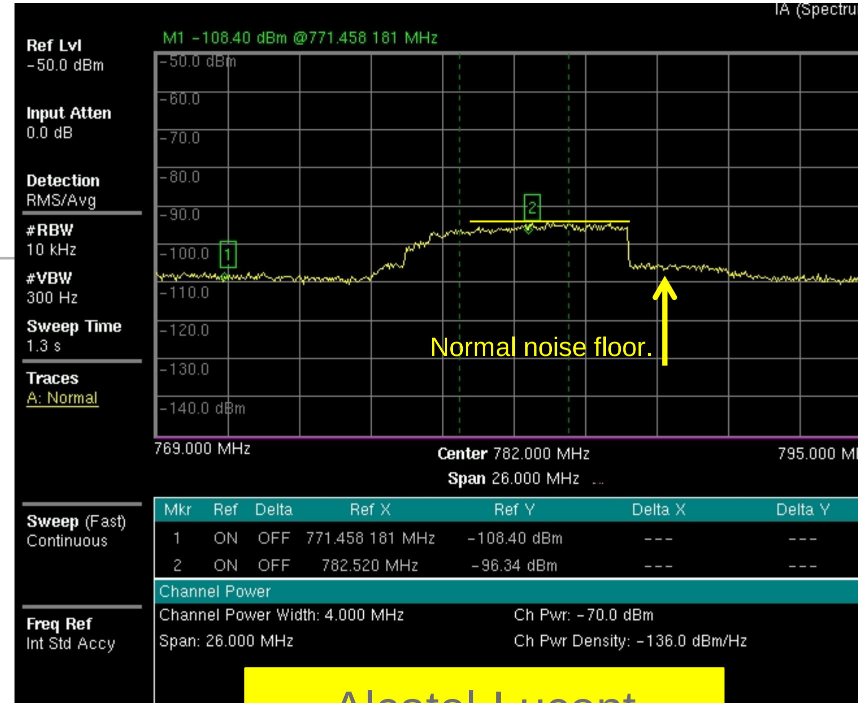
UE Response to interference in Ericsson

- UE does not increase power
- MCS is reduced to match the degraded SINR at the receiver

Path loss based power control
Performance vs Noise (Ericsson)

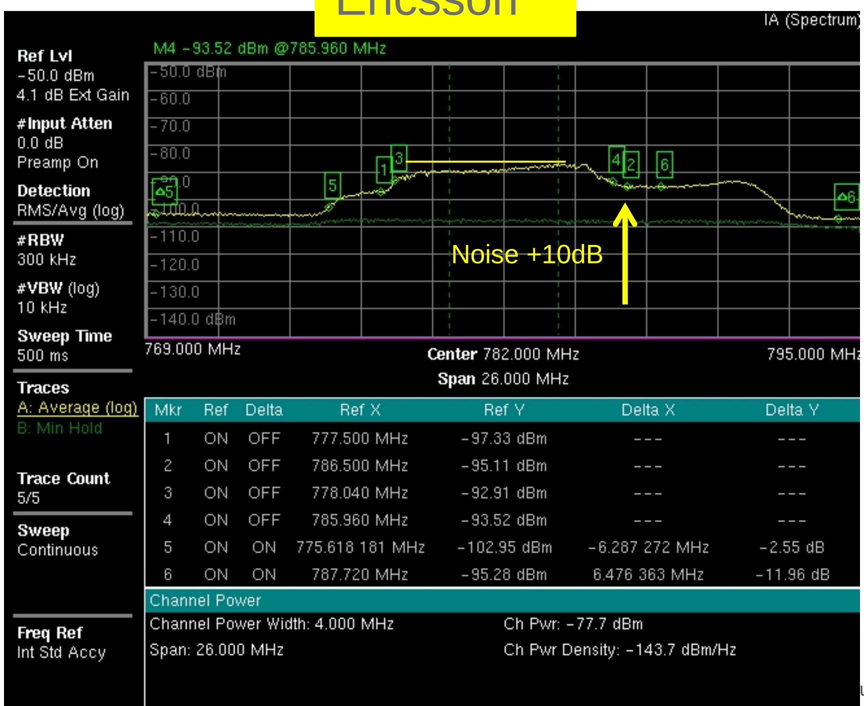


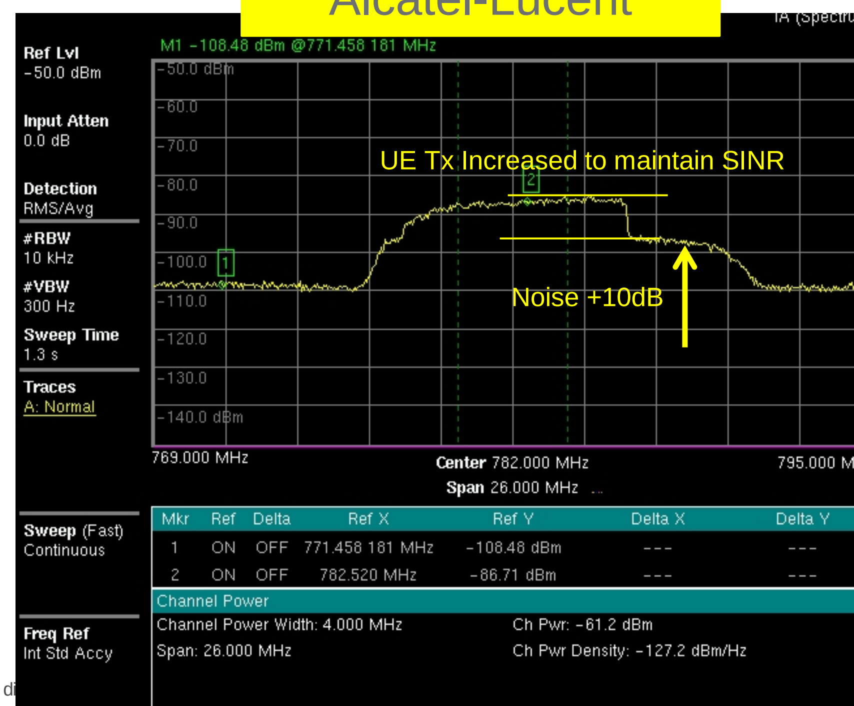




Ericsson

Alcatel-Lucent





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- **Non-invasive PIM testing**
- Path balance
- Effects of power scaling

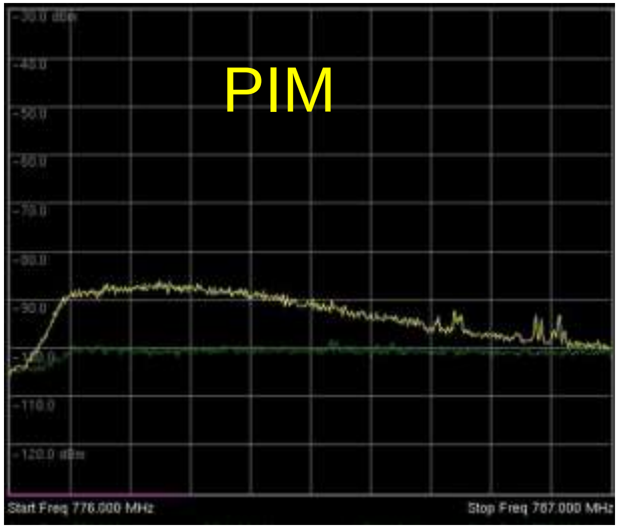
Non-Invasive PIM Detection Using eNodeB Rx Ports

-Use OCNS or AILG to force all radios to full power

-Monitor the receive spectrum for PIM signature that correlates with the power up

-Using MIN HOLD features may assist the detection of a constant PIM problem in the presence of significant UE activity

-The PIM slope will always be highest toward the transmit frequency



PIM Mitigation

Connect spectrum analyzer to receive monitor port(s) on the eNB or monitor receive power levels using another mthod

Isolate the eNodeB from the DAS

If noise clears, look toward DAS

If noise continues, troubleshoot from that point back towards the eNB

PIM Mitigation

- While monitoring the spectrum analyzer, disconnect remote fibers from the BU, one at a time until you see the noise floor go down
- This will isolate the location of the remote in trouble

PIM Mitigation

- There may be more than one remote device causing the issue
- Document the location of the remote/remotes in question

Topics-

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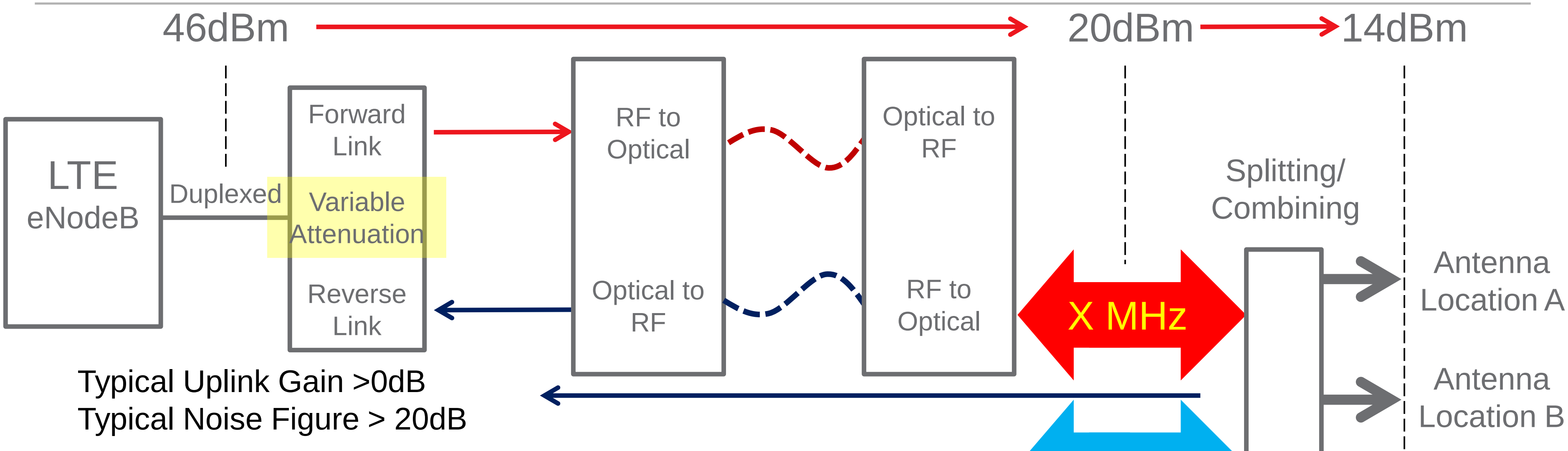
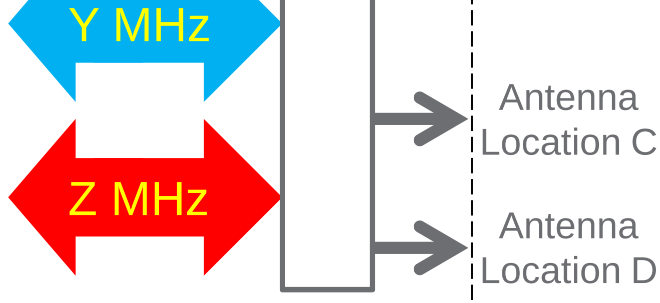
Where does the path imbalance come from?





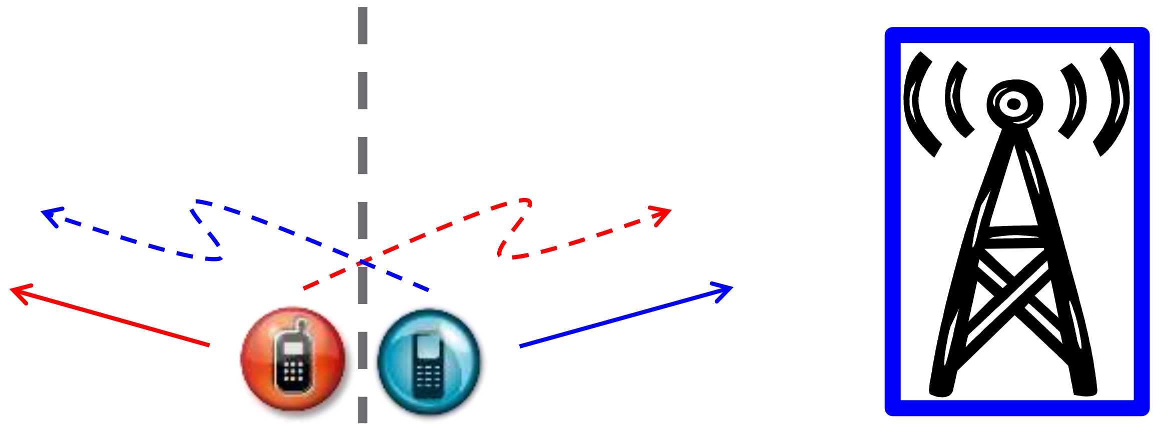
Downlink perceived loss 32dB (46dBm – 14dBm)
Uplink gain > 0dB (specified)

This is a path imbalance of > 32dB!!!

Uplink Noise Figure 20dB to 24dB

This is a 20dB Rise Over Thermal!!!

Balanced forward and reverse link

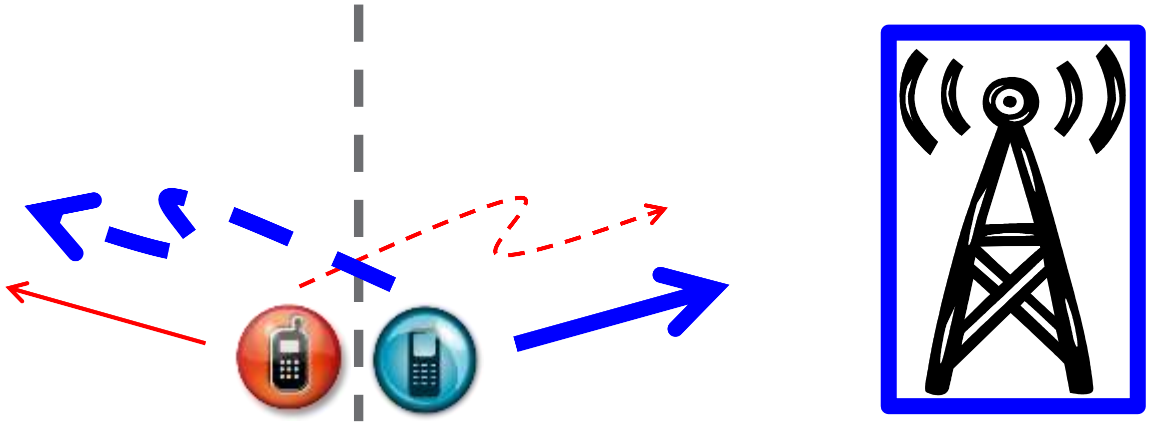


Equal RSRP Boundary
(Cell Edge)

- UEs at the DAS cell edge transmit at the same levels as the macro UE’s
- Inter-cell interference is the same for both receivers

What if the path is not balanced?

- Scenario 1 – The DAS uplink path has less attenuation than the downlink

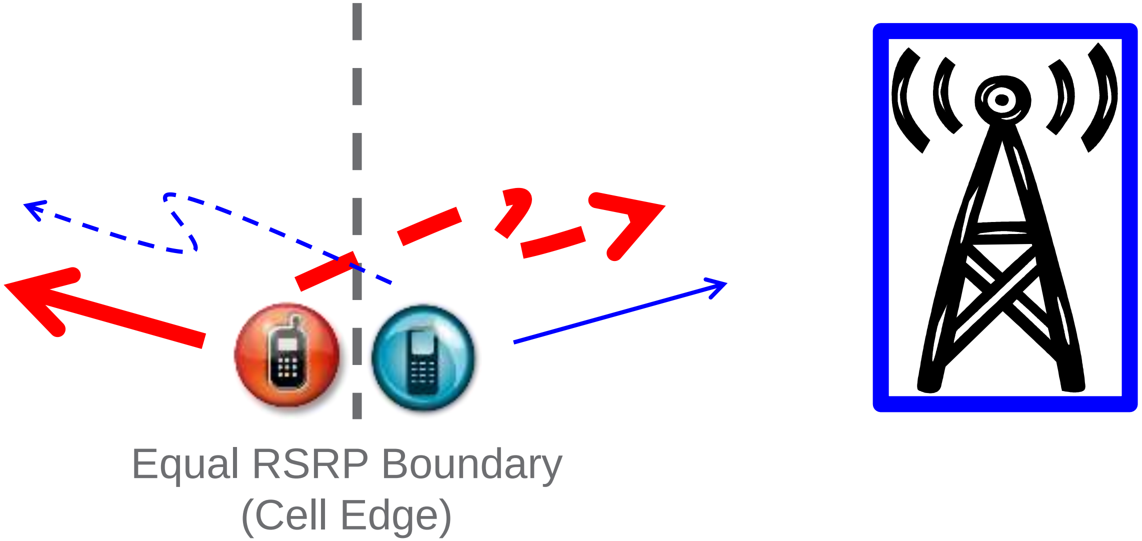


Equal RSRP Boundary
(Cell Edge)

- UEs at the DAS cell edge transmit less than they should which allows adjacent sector UE transmissions to cause interference to the DAS affected DAS receivers which degrades performance and creates instability
  – Ericsson DAS uplink performance will slow down
  – Alcatel-Lucent fractional power control algorithms will force DAS UEs to power up after a few seconds creating a stability problem for the DAS

What if the path is not balanced?

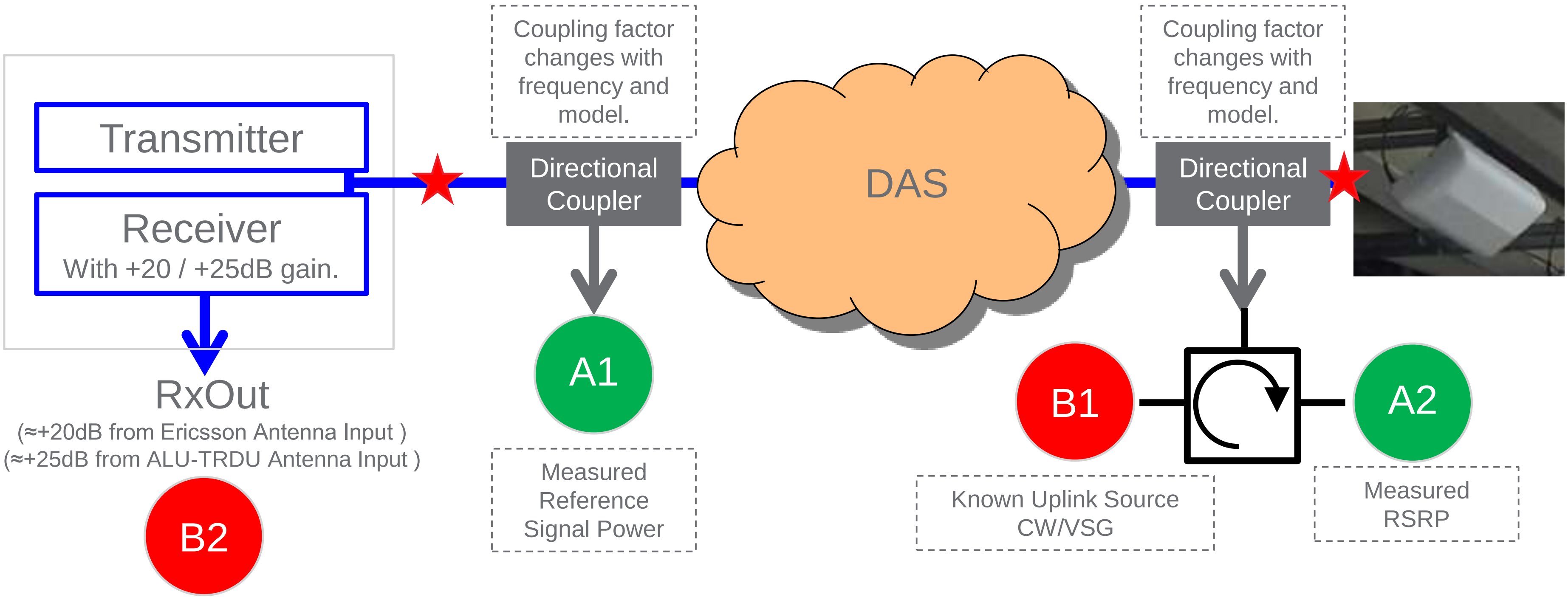
- Scenario 2 – The DAS uplink path has more attenuation than the downlink



- UEs at the DAS cell edge transmit more than they should generating inter-cell interference to adjacent sectors which degrades performance and creates instability
  - Ericsson uplink performance will slow down
  - Alcatel-Lucent fractional power control algorithms will force adjacent sector UEs to power up (if possible), creating increased inter-cell interference on the DAS

Measuring Path Balance

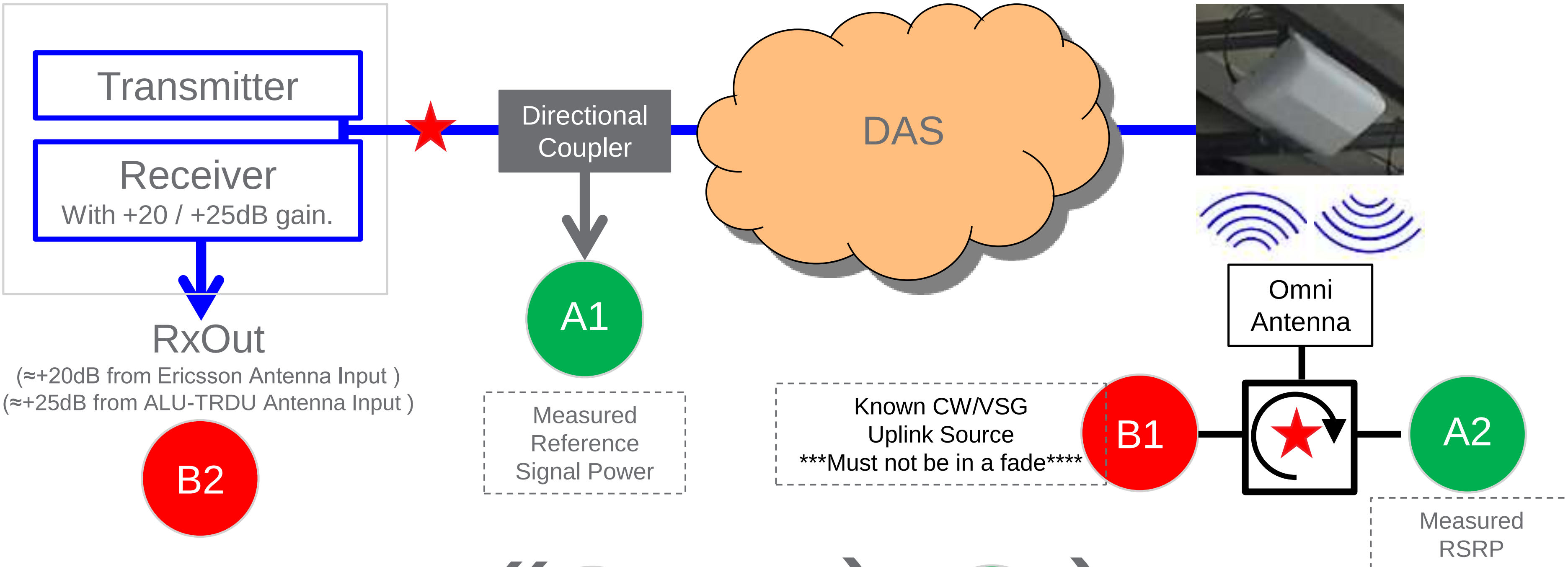
Path Balance Measurement with Couplers



Forward Link Pathloss = ((A1 + Coupling) - (A2 + Coupling))

Reverse Link Pathloss = ((B1 + Coupling) - (B2 - LNA GAIN))

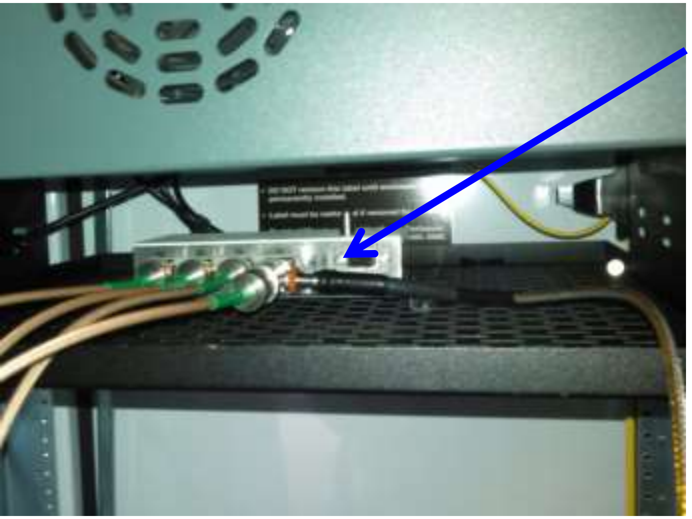
Path Balance Measurement Over the Air
Beware of Fading Effects



Forward Link Pathloss = ((A1 + Coupling) - A2)

Reverse Link Pathloss = (B1 - (B2 - LNA GAIN))

Remotes may also have couplers available.

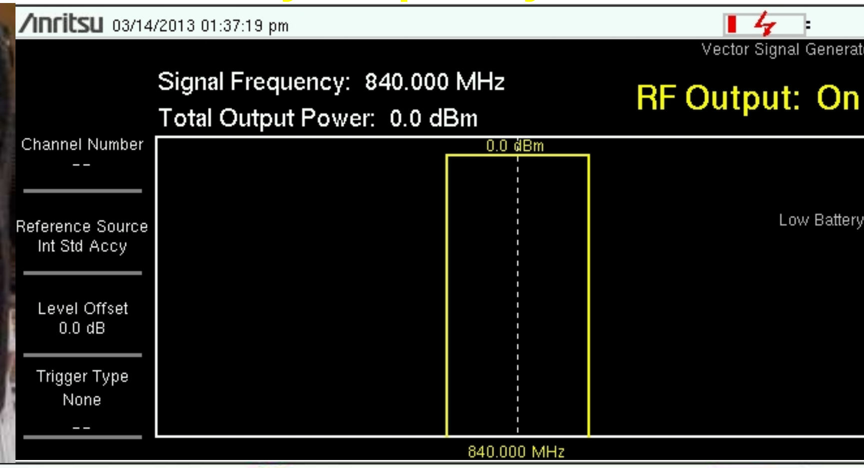


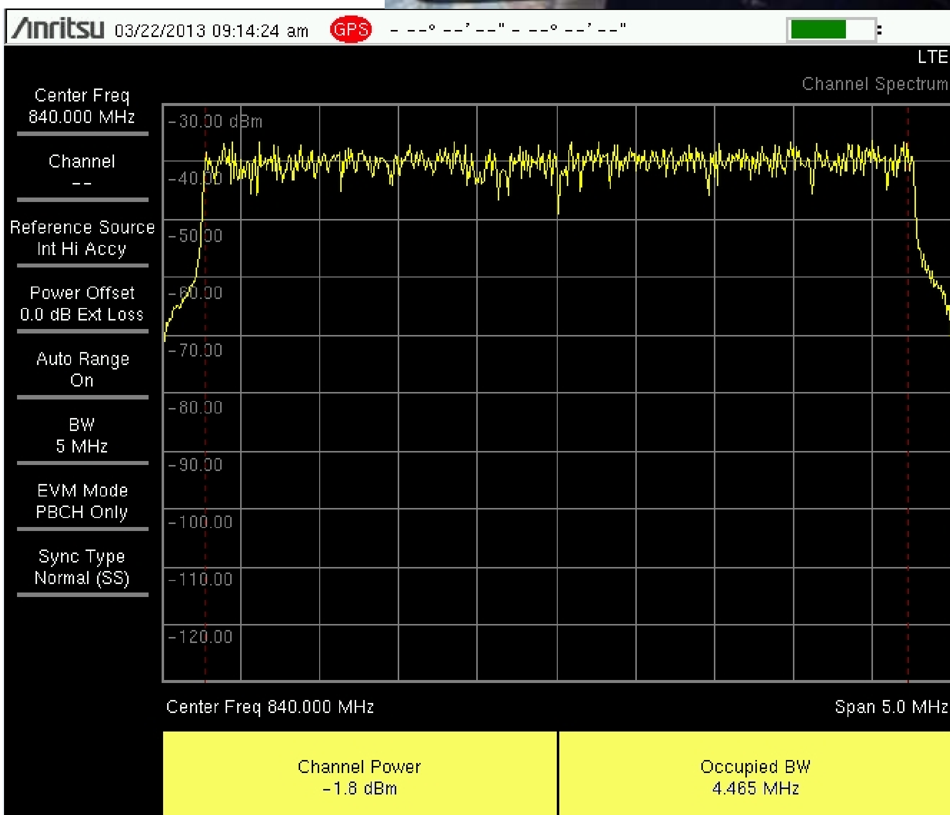
- Accurate forward link measurements can be made at a coupled port if installed at the remote.
  - Coupling values will be different per band.
  - Pilot, RSRP, Channel Power can be measured.
- Signals may also be injected using the coupled port for reverse path measurements assuming the coupled port is bi-directional.
  - Coupling values will be different per band.

Potential injected signals for reverse link measurements:

- Continuous Wave (CW)
- Vector Signal Generator (VSG)

A VSG with a -25dBm RSRP at any frequency allows for channel and quality estimation on any frequency.





Using Expected Transmit Power to deduce path balance on Ericsson

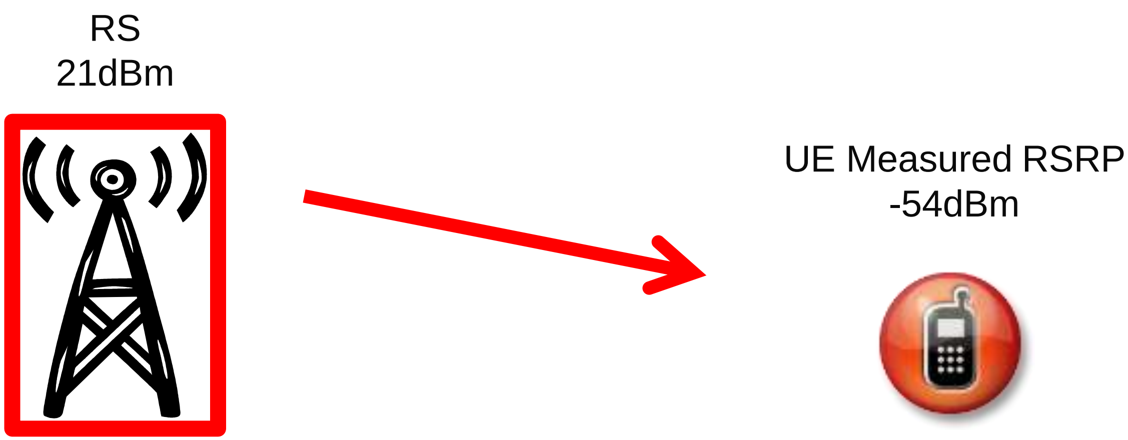
- Ericsson P0 power control targets are very predictable and can be used to determine path balance on Ericsson LTE systems

- Average PUCCH Transmit Power should reach an steady state while downloading and is directly related to uplink path loss

- Average PUSCH Transmit Power should reach a steady state while uploading but the number of scheduled physical resource blocks can significantly change the PUSCH power

- Deviations from the expected values are path imbalances when compared to normal balanced path operation

Example PUCCH Tx Calculation



Calculated downlink path loss = 21dBm – (-54dBm) = 75dB

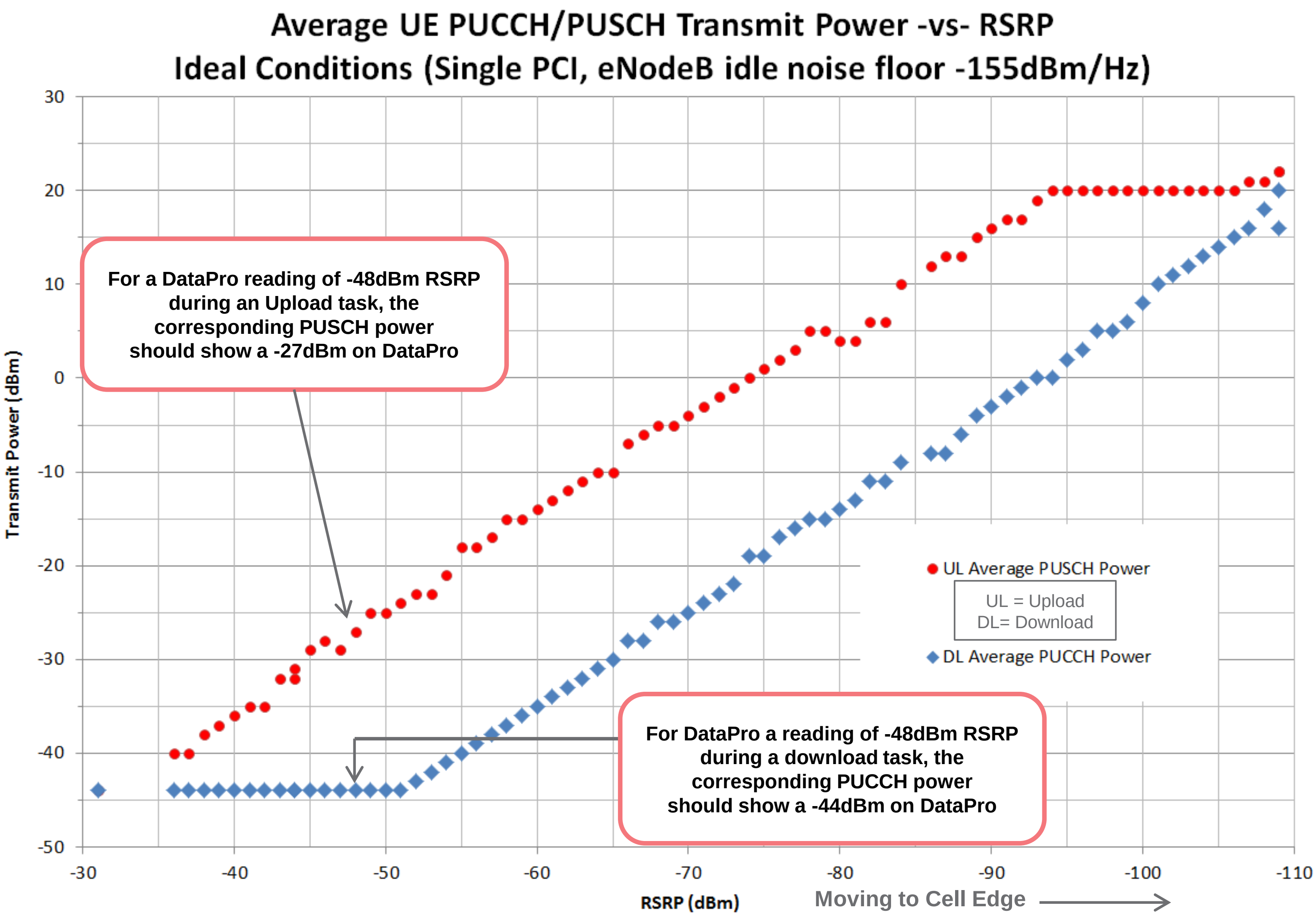
Expected UE PUCCH Transmit Power = P0PUCCH Target + Path Loss
-113dBm + 75dB = -38dBm

PUCCH Tx levels <-38dB indicate an uplink path loss that is less than the downlink

PUCCH Tx levels >-38dB indicate an uplink path loss that is more than the downlink

Characterizing normal LTE balanced path operation

Closed Loop Testing at EnodeB (Ericsson fed system)



Using Expected Transmit Power to deduce path balance on ALU.

- Alcatel-Lucent Closed Loop Power Control Algorithms always target SINR, not pathloss regardless of FPC and IoT settings.

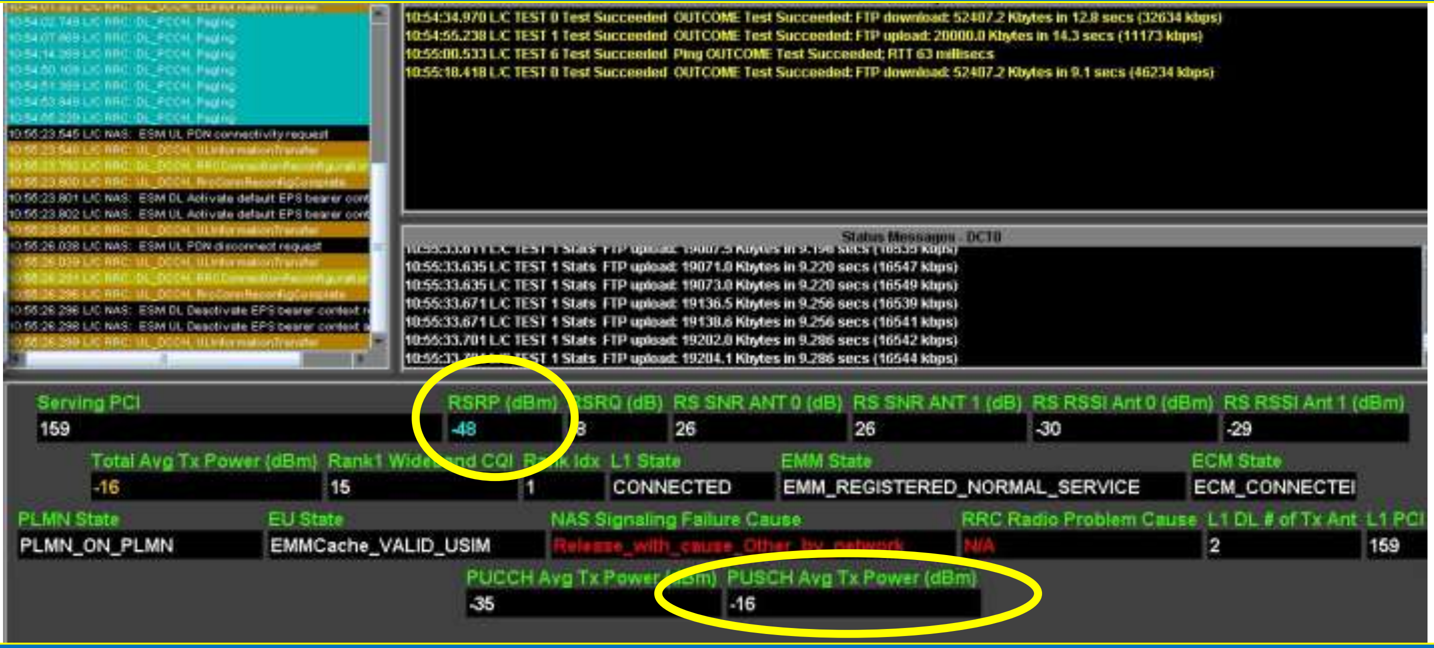
- Any interference or rise over thermal will force UE transmit levels to increase. This makes it difficult to use expected transmit levels to balance forward and reverse links on an ALU system.

- An expected PUCCH transmit power curve can be generated and applied fairly easily but it will only be applicable in similar interference conditions with the same FPC and IoT settings.

Datapro

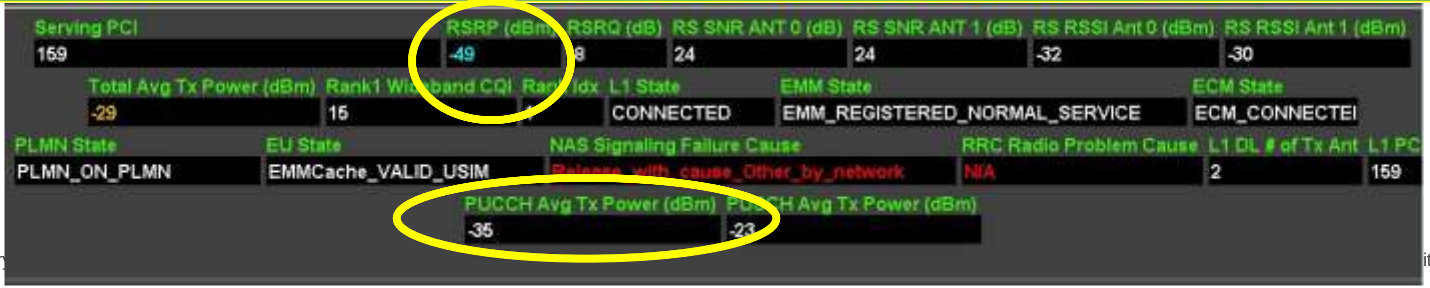
-DPDM During Upload –

Given any RSRP, Path Balance can be estimated using the Average PUSCH Transmit Power.



-DPDM During Download –

Given any RSRP, Path Balance can be estimated using the Average PUSCH Transmit Power.



Know Your Test Equipment

Practice measurement methods on normal systems

- Measure path balance on a macro system eNodeB to make sure your setup is telling you what you think it is. Free space is balanced

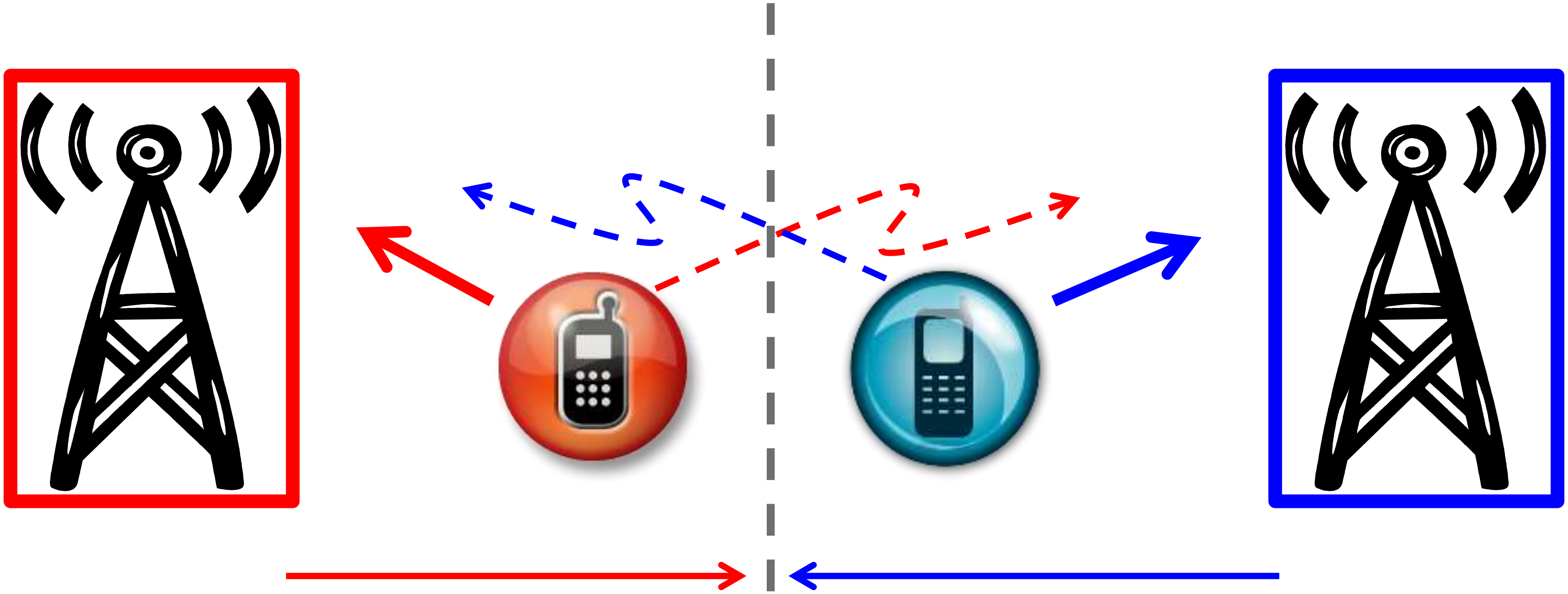
- Measure the noise floor on an eNodeB attached to a load to fine tune your measurement setup and expectations.

- Go to equal RSRP boundaries and check UE PUCCH transmit levels on the DAS and macro system at the same RSRP

Effects of power scaling on inter-cell interference (ICI)

Macro Network Example of Inter-Cell Interference

Inter-cell Interference is the same for both sectors given the same Operational Path Loss and P0Nominal Targets.

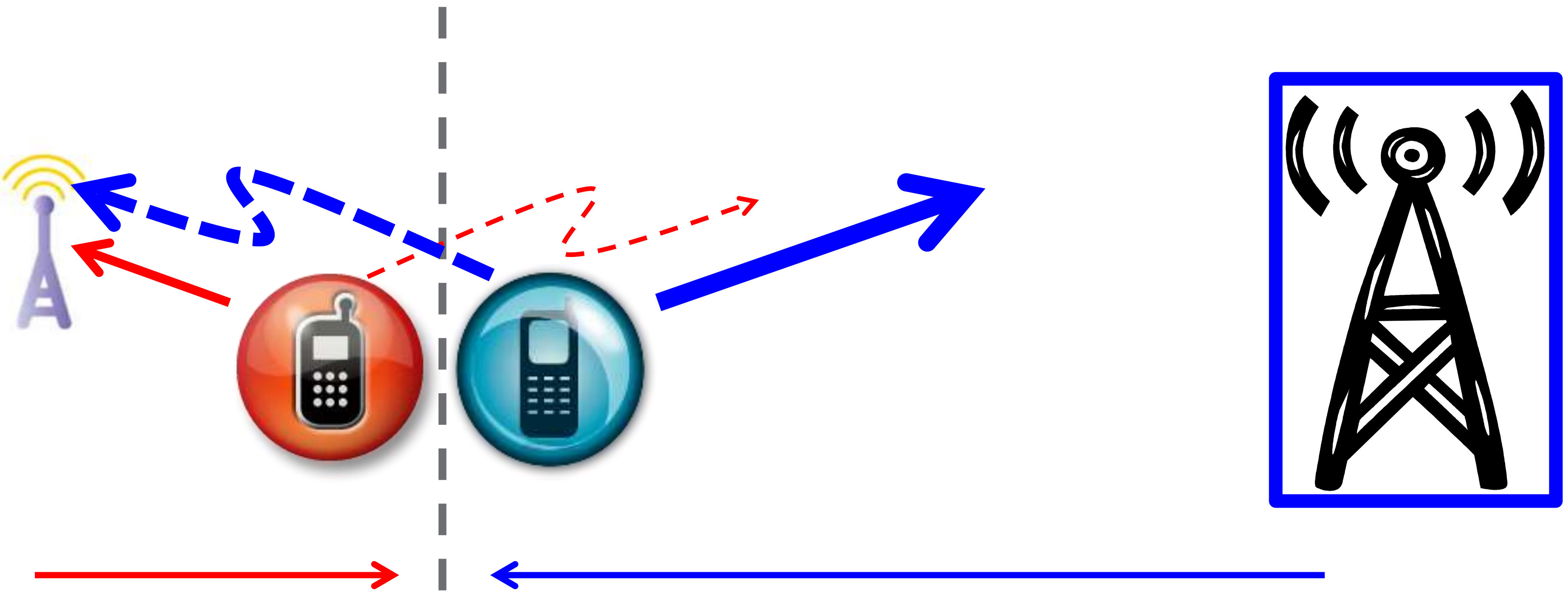


Device transmit power increases as it moves towards cell edge.

Device transmit power increases as it moves towards cell edge.

Small Cell Example of Inter-Cell Interference

Inter-cell Interference is much worse for the lower power cell.
UE transmission power is much higher for the blue UE given the higher Operational Path Loss.

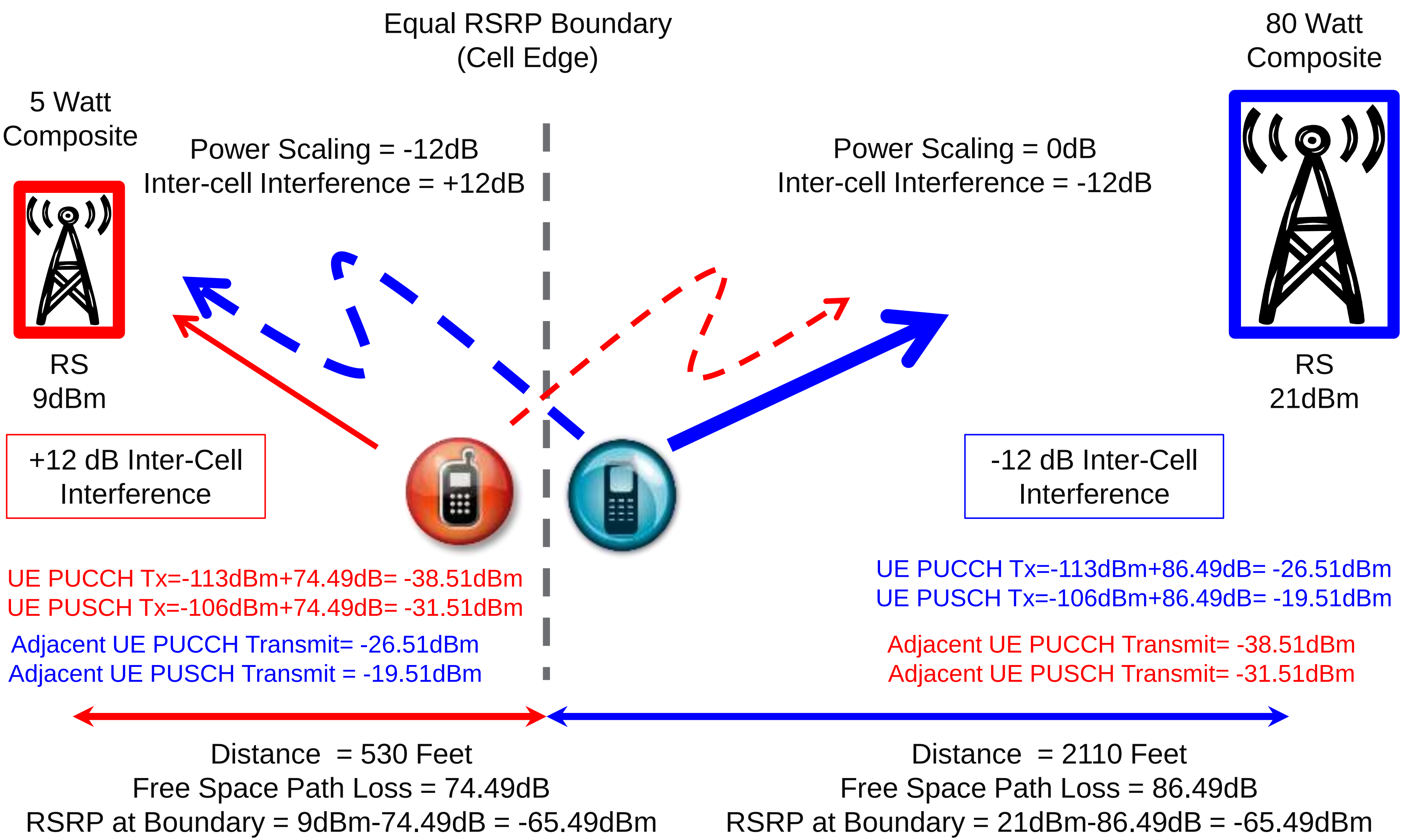


Equal RSRP Boundary
(Cell Edge)

Device transmit power continues to increase to as it moves towards the blue cell edge.

Example: 5W Small Cell in a 80W macro system

Frequency 782MHz, Reference Signal 21dBm, Distance Between Cells 2640 Feet
PUCCH Target -113dBm, PUSCH Target -107dBm



Potential ICI mitigation methods…

The open loop case…

-Increased ICI can potentially raise the noise floor for RACH processes causing failures during setup and handoff

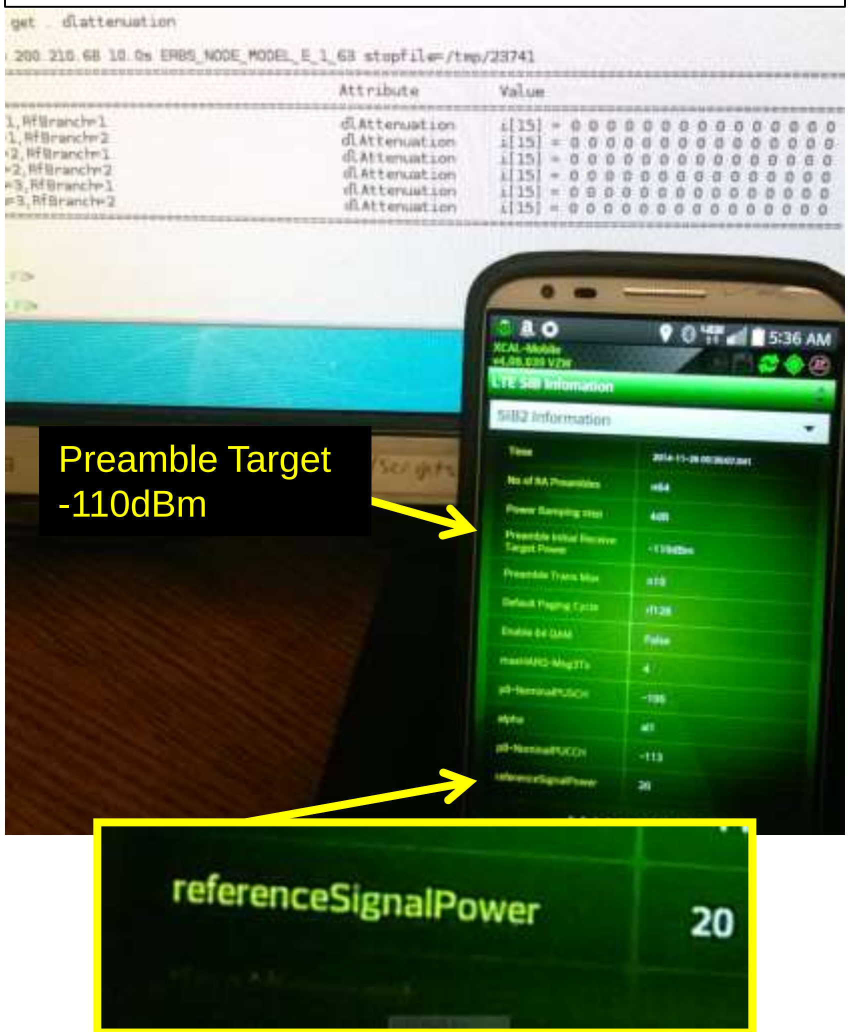
-PUCCH, PUSCH, and Preamble targets can be raised or downlink attenuation can be included to force the UE to transmit more power during access attempts

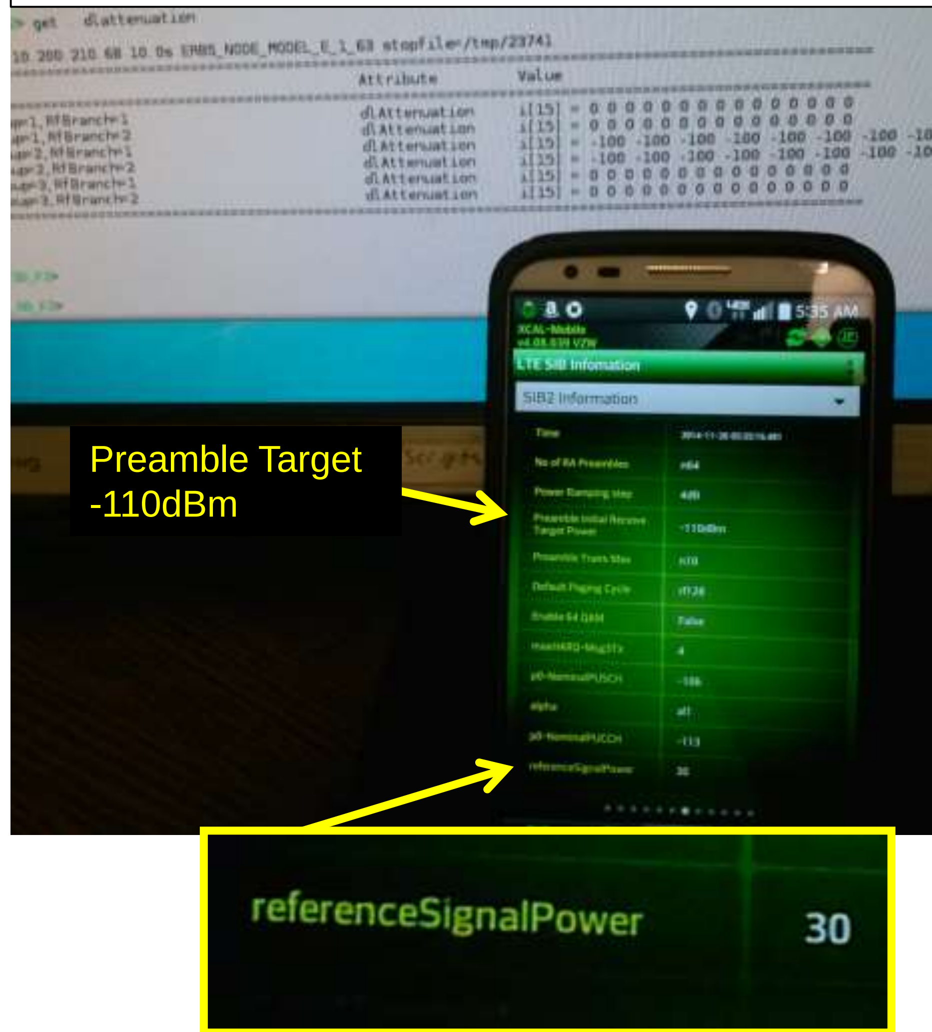
-Be very careful when adjusting targets to accommodate ICI associated with low power cells. Aggressive changes can impact macro-cell ICI as well. Changes that are made should not be visible on adjacent macro cells

-If adjacent cell RSSI/interference levels increase after open loop adjustments are included then consider scaling back the change by that amount or more

E/// Downlink Attenuation effect on SIB2 Reference Signal Information for Open Loop Est.

DLAttenuation = 0 (Normal RS=20)	DLAttenuation = -100 (RS=30)





Potential ICI mitigation methods…

<u>The closed loop case…</u>

-Increased ICI can noise floors for the PUCCH and PUSCH channels degrading uplink throughput

-Uplink attenuation can be added to mitigate increased ICI. This will raise UE transmission levels but will also increase the uplink noise figure

-P0PUCCH and P0PUSCH targets can also be increased

-Be very careful when adjusting targets to accommodate ICI associated with low power cells. Aggressive changes can impact macro-cell ICI. Changes that are made should not be visible on adjacent macro cells receive or interference levels.

-Review adjacent sector RSSI/interference levels- Increased interference may reflect increased ICI. Consider reducing target increases

How much is enough??

-Changing targets to accommodate inter-cell interference can be harmful

-**<u>Go to an equal RSRP border and experience the problem before making changes</u>**

-Use reported RSSI and BLER metrics to determine if adjacent cells are being harmed due to increased targets

-Monitor low power eNodeB RSSI and BLER trends to validate the presence of ICI under load and to make sure adjustments have positive impact

Summary…

-Define clear objectives

- Noise levels
- Path balance
- PIM
- Scaling considerations

-Test assumptions

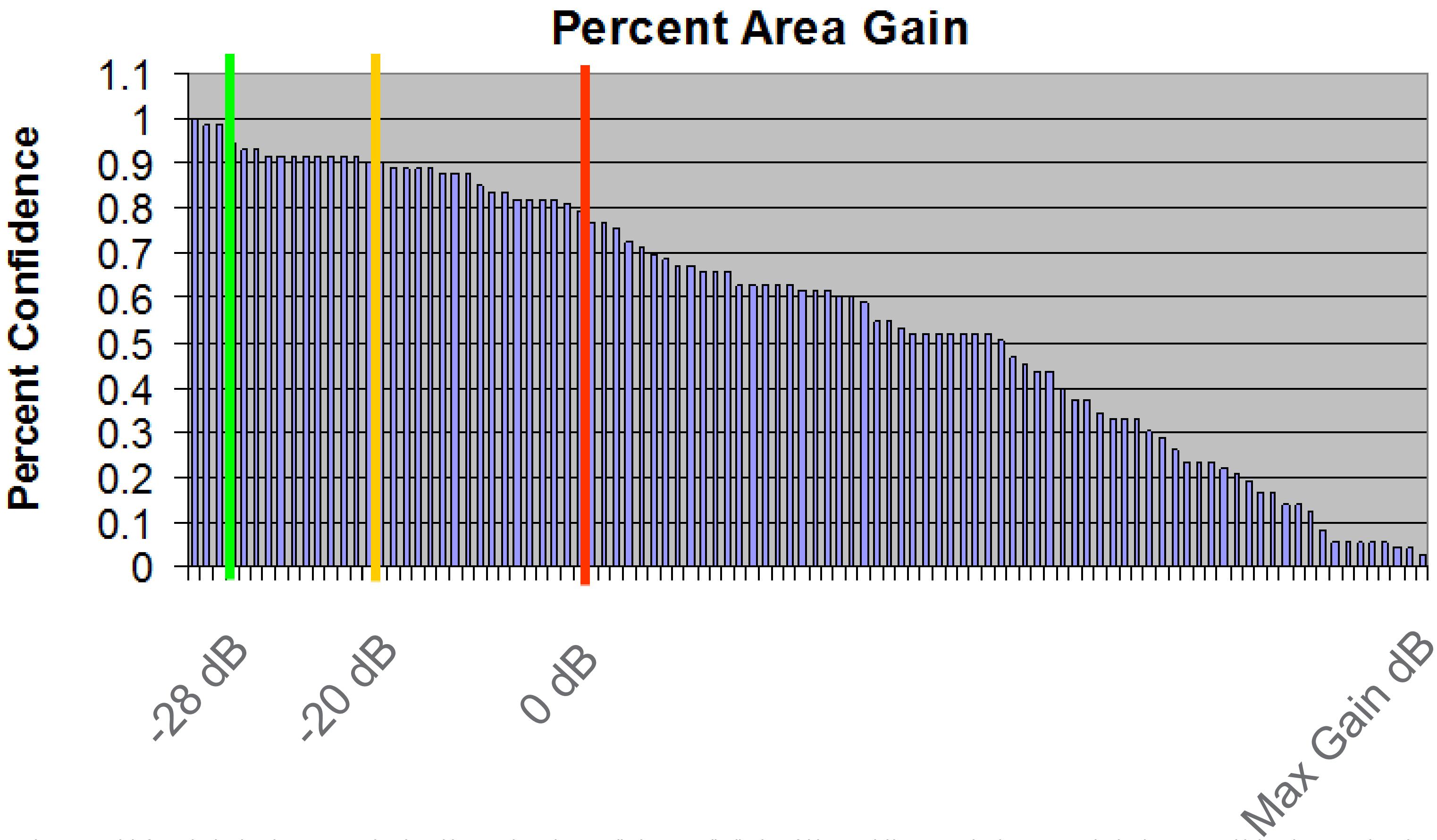
- Load antenna inputs and review metrics
- Verify measurement methods by testing known sources
- Visit equal RSRP boundaries and study open loop and closed loop UE behavior differences

-Maintain quality control and establish pre-season routines to revisit and test systems annually

-Thank You!-

Focus on Patterns and Efficiency Not Just Gain

- 95% of values are greater than -28 dB
- 90% of values are greater than -20 dB
- 80% of values are greater than 0 dB



Where did the Tx/Rx Monitoring ports go?

- Newer low power radio units such as the mRBS, mRRU, and MRO lack coupled ports and receive taps which make them more difficult to integrate and trouble-shoot

- Adding bi-directional couplers to feed lines will provide access to measure the downlink (and uplink with enough margin). These coupled ports can also be used for over the air testing if a mag-mount is attached

- CPRI analyzers provide real time spectral analysis and advanced features when ports are not available

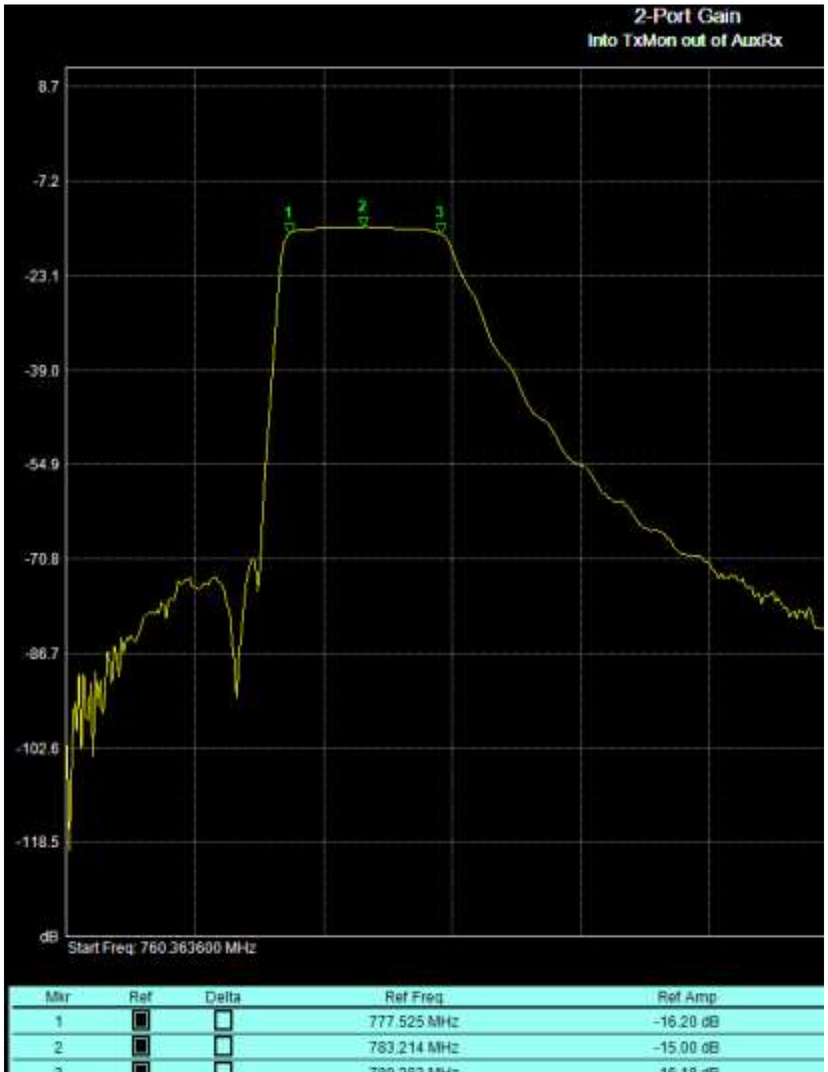
$$P_{PUSCH} = \min\{P_{max}, 10 \times \log 10 M + P_0 + \alpha \times PL + \delta_{mcs} + f(\Delta i)\}$$

- P_{max} is the maximum allowed transmit power.
- M is the number of physical resource blocks (PRB).
- P_0 is cell/UE specific parameter used to control the SNR target and compensate for cell specific noise conditions.
- α is the path loss compensation factor used for fractional power control.
- PL is the downlink pathloss estimate based on RSRP measurements and known transmitted reference signal power.
- δ_{mcs} is a cell/UE specific modulation coding scheme value.
- $f(\Delta i)$ is the closed loop correction value with a UE specific TPC control.

UE specific Power Headroom Reports (Ericsson) and Sounding Reference Signals (ALU) are used to estimate uplink channel condition and quality for uplink transmission control.

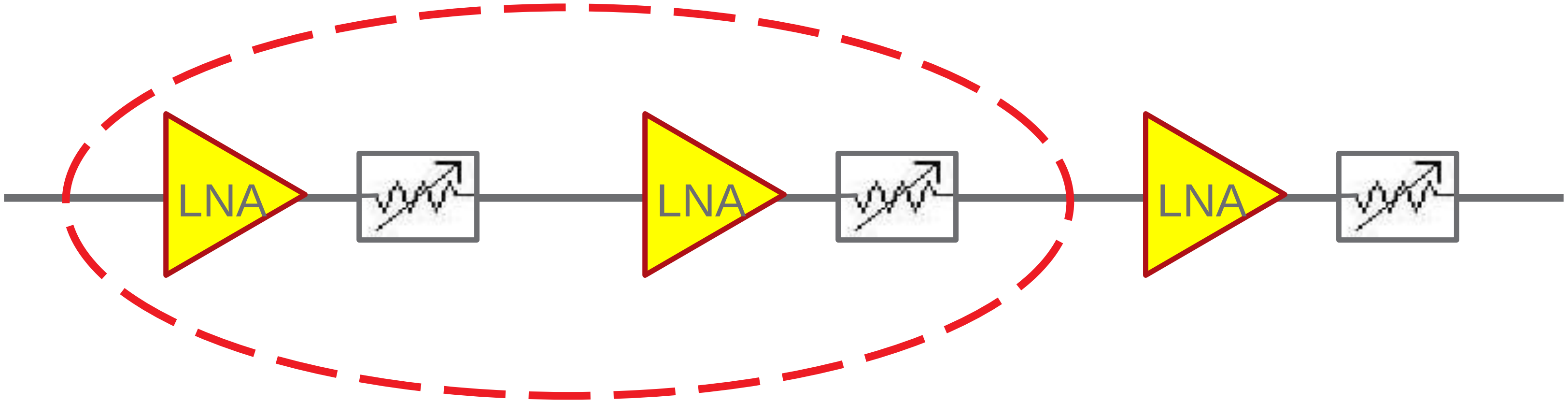
3GPP “E-UTRA Physical layer procedures”, TS 36.213 V8.1.0

ALU TxMon port is bi-directional



- Downlink coupling is ≈ 40.4dB
- Two port gain measurement into the TxMon port and out of the AuxRx port are -15dB to -16dB
- Estimated uplink gain is -15dB + 40.3dB = 25.3dB
  - Check: -174dBm/Hz + 25.3dB = -148.7dBm/Hz
  - Noise floor measurement = -146.8dBm/Hz
  - Est. LNA NF -146.8 – (-148.7) = 1.9dB
- PUCCH path balance measurements confirm bi-directionality of this port
- Connecting a small antenna to this coupled port provides a simple way to perform basic operational tests

Optimizing Noise Figure



$$F_{total} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} + \ldots + \frac{F_n - 1}{G_1 G_2 \ldots G_{n-1}}$$

$$F = \frac{\mathrm{SNR_{in}}}{\mathrm{SNR_{out}}}$$ (linear)

$$F_n = 10^{NF/10}$$ (linear)

$$\mathrm{NF} = 10\log(F) = 10\log\left(\frac{\mathrm{SNR_{in}}}{\mathrm{SNR_{out}}}\right) = \mathrm{SNR_{in,dB}} - \mathrm{SNR_{out,dB}}$$ (decibels)