10 Steps to Determine 3G/4G IP Data Throughput

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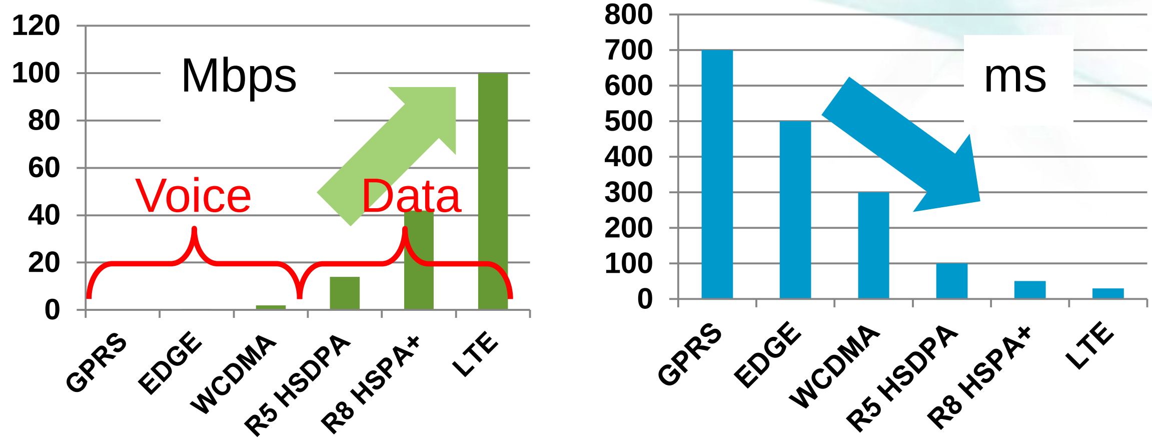
Agenda

- **Introduction**
- **10 Steps to Data Throughput Testing – building up complexity**
- **Case studies – “peeling back the onion”**
- **Summary**

Technology Drivers for Wireless Networks

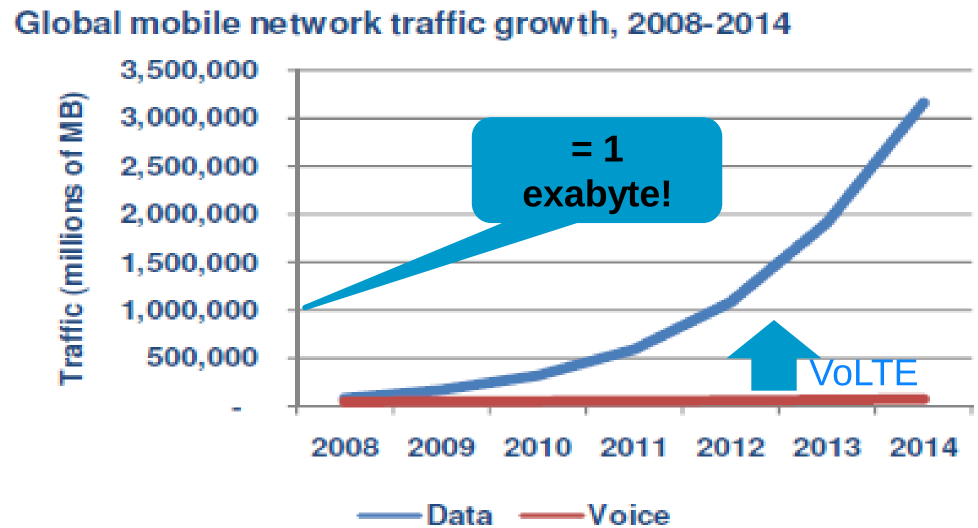


- **Higher speed,**
- **Lower latency**
- **All IP**
- **Convergence (Radio Access and Core Networks)**
  - **LTE and IMS**
- **Interworking**

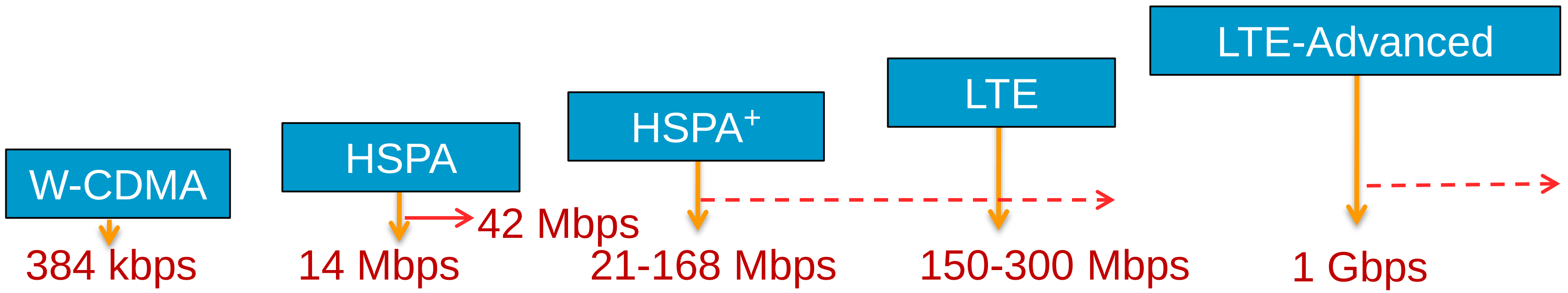
E2E IP Throughput Testing is a key performance test which aligns with these technology drivers

It's All About More Data, Faster!

- Mobile penetration continues to grow: > 5 billion subscribers worldwide – more than 70% penetration*
- Mobile data traffic is growing exponentially - caused by growing number of mobile devices such as tablets and smartphones accessing high-bandwidth applications.
- More spectrum is being made available
- In addition to subscriber growth, there is parallel growth in cellular peak data rates



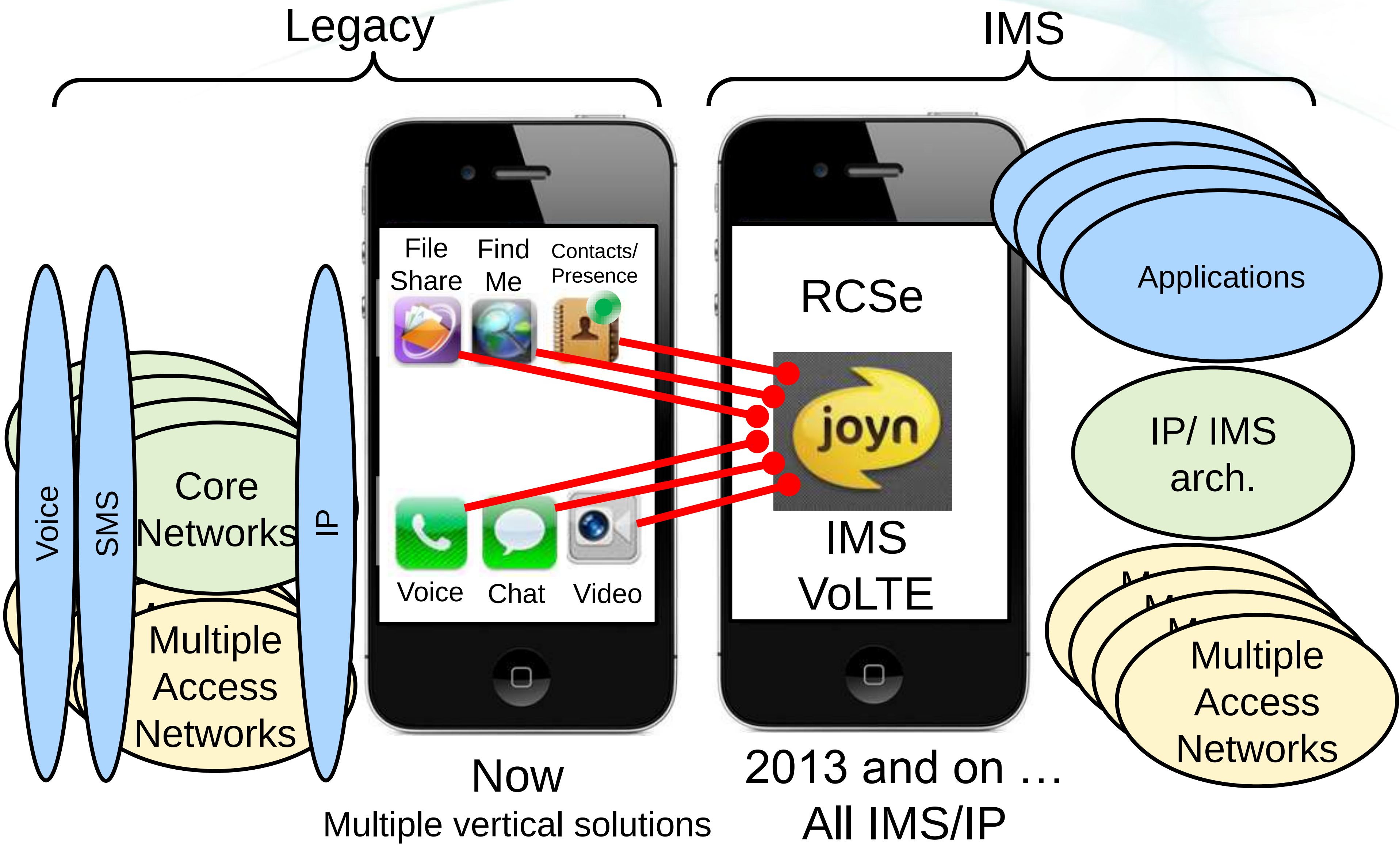
Source: LTE World Summit presentation 2011



Growth in cellular peak data rates (theoretical) showing more than 2500 times higher data rate over a period of 10 years

* Note some users have multiple subscriptions

IP Multimedia System (IMS) Convergence



Traditional Data Channel Testing Methods

Physical layer testing

- Benefits: Verifies coding and basic performance of L1
- Issues: Does not include higher layers, signaling, or apps

Standards-based testing

- Benefits: Industry standard, repeatable, required for conformance
- Issues: Does not include apps, limited configs tested, ideal conditions

  Often does not match real user experience

Traditional Data Channel Testing Methods

Field testing

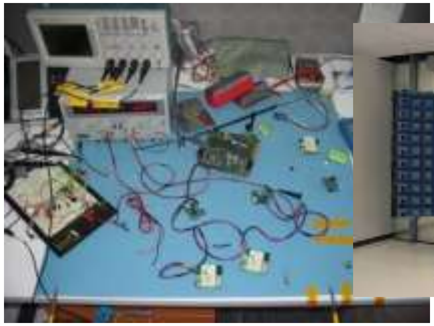
– Benefits: Real world conditions, can include apps

– Issues: Not repeatable, often requires travel, difficult to troubleshoot and time consuming

Proprietary test systems

– Benefits: Repeatable test scenarios, in house 24x7 access

– Issues: Requires large investment $$ and time plus dedicated staff



E2E IP as a Measurement

- Benefits
  - A simple measurement to make yielding quick results
  - Tests a key performance parameter vs a headline theoretical limit
  - Is a stress test that tests the complete phone
  - Excellent at finding if you have a problem
- Issues
  - Not so good at isolating what your problem is!
  - Sometimes finds problems with the test and not the phone

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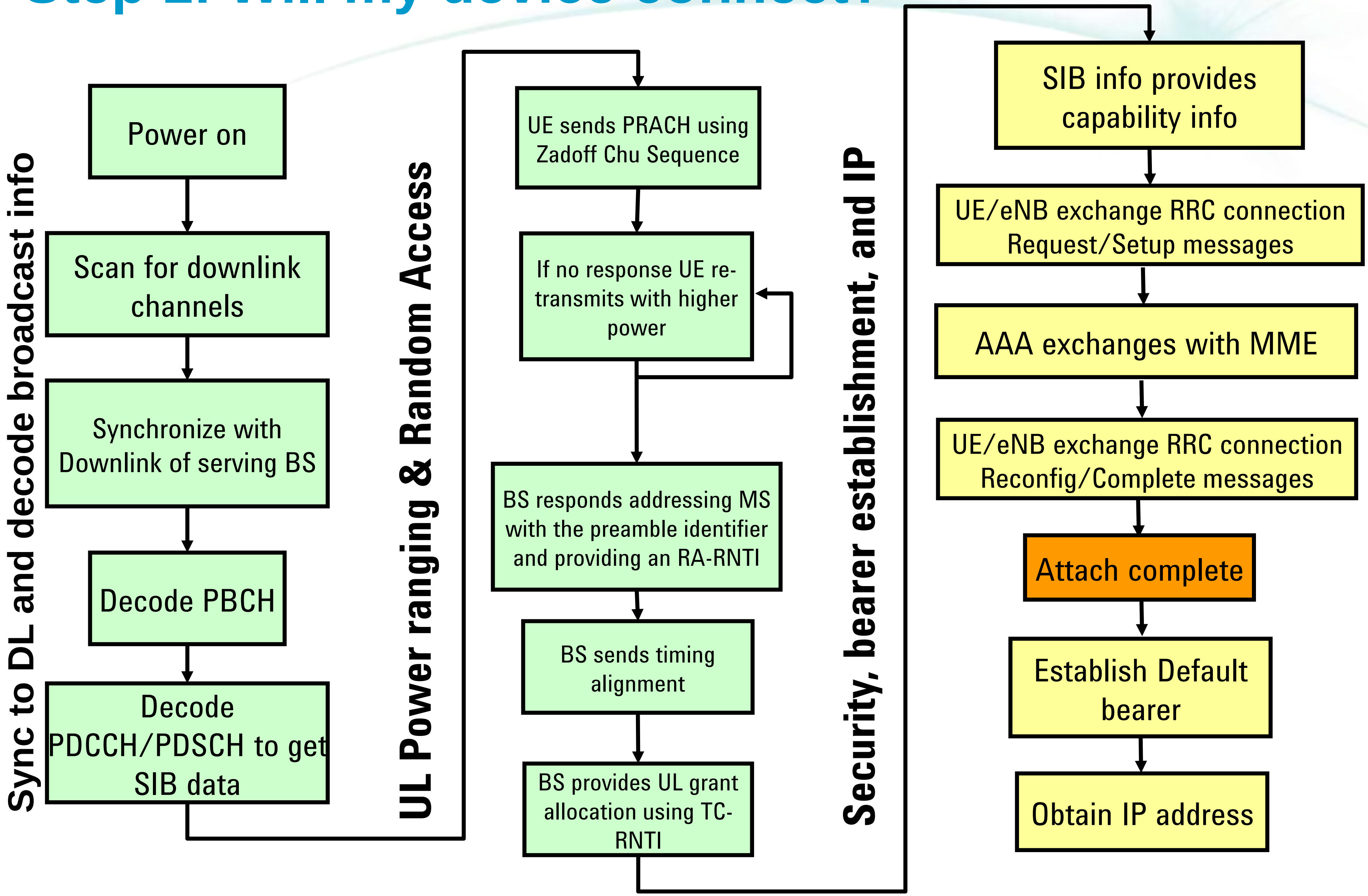
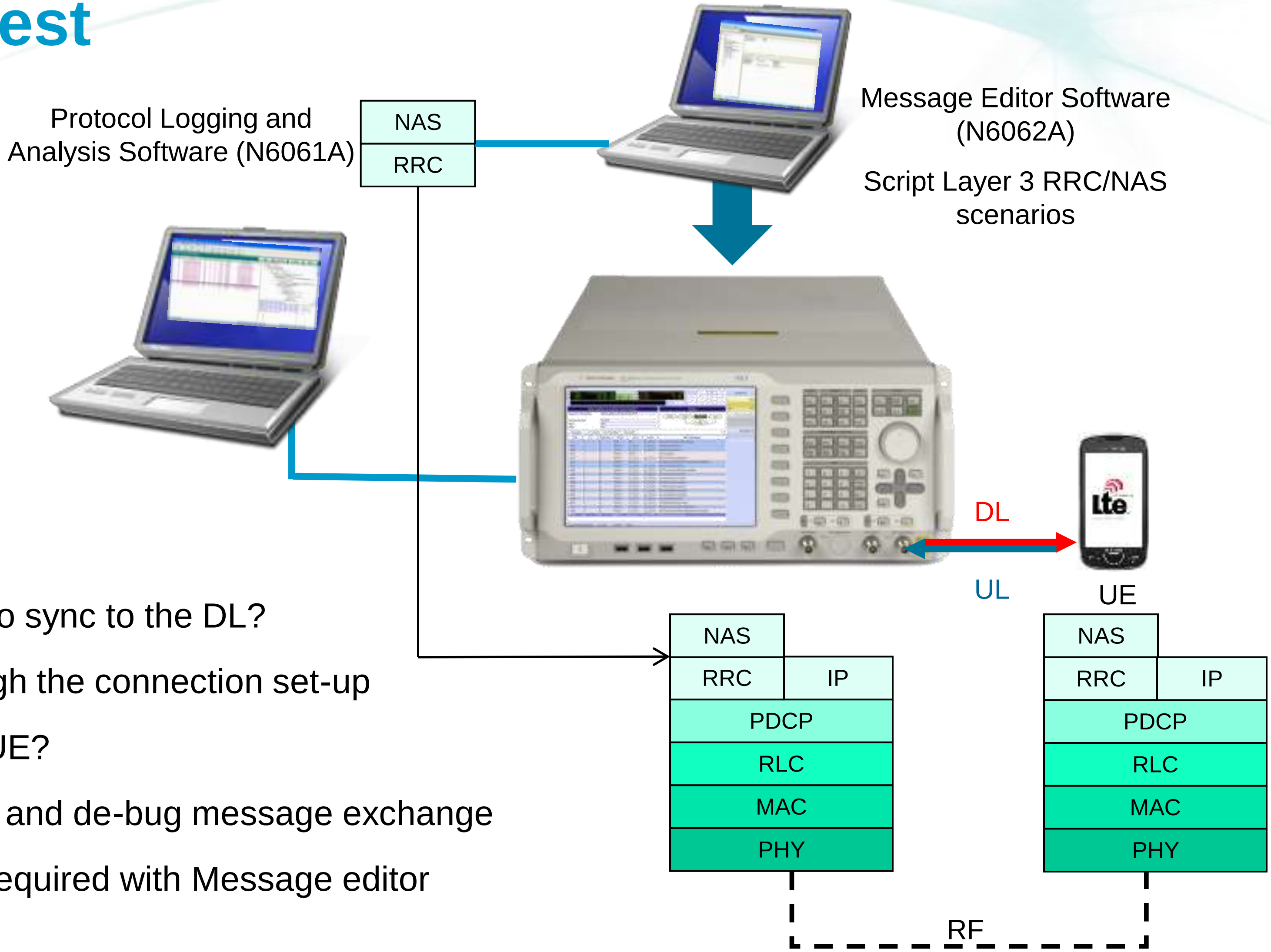
E2E IP … 10 Step Plan, building up complexity

1. Will my device connect?
2. Do I have a good quality transmitter?
3. Do I have a good quality receiver?
4. Can I achieve max E2E tput under ideal conditions with UDP
5. What about with TCP and simultaneous UL/DL?
6. What happens if I try real application?
7. What happens under non-ideal conditions?
8. Is it robust?
9. Does it work closed loop?
10. How good is my battery life?

Step 1: Will my device connect?



1. Will my device connect? Protocol test



- Is the UE able to sync to the DL?
- Can I get through the connection set-up
- Can I ping my UE?
- If not take a log and de-bug message exchange
- Make edits as required with Message editor

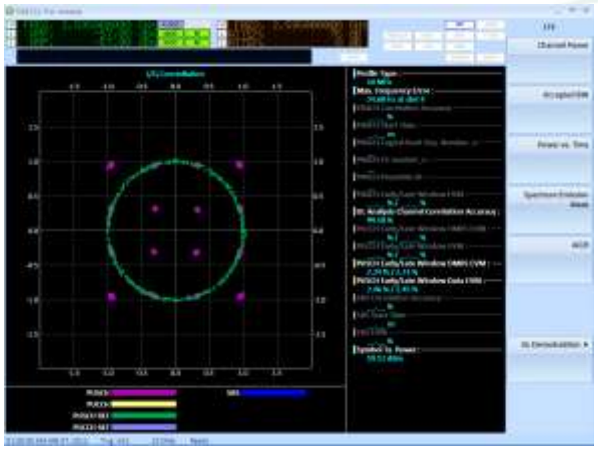
2. Do I have a good quality Transmitter?
RF test

- High data throughput testing relies on good quality UL transmissions
- Look for the following:-
  - Ensure you have appropriate power and attenuation settings
  - High EVM for high order modulation schemes
  - High EVM at the band edge
  - Spurs both in band and out of band
  - Linearity issues/ spectral growth
  - Switching transients, LO settling time
  - Repeat tests with any “other” radio’s active

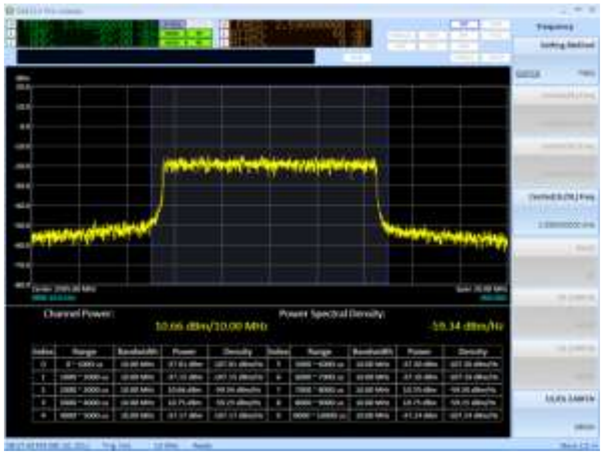
3GPP Tx Measurements

Test case Number	3GPP 36.521 Test Case Description
6.2.2	UE Maximum Output Power
6.2.3	Maximum Power Reduction (MPR)
6.2.4	Additional Maximum Power Reduction (A-MPR)
6.2.5	Configured UE transmitted Output Power
6.3.2	Minimum Output Power
6.3.3	Transmit OFF Power (Covered by 6.3.4.1)
6.3.4.1	General ON/OFF time mask
6.3.4.2.1	PRACH time mask
6.3.4.2.2	SRS time mask
6.3.5.1	Power Control Absolute power tolerance
6.3.5.2	Power Control Relative power tolerance
6.3.5.3	Aggregate power control tolerance
6.5.1	Frequency error
6.5.2.1	Error Vector Magnitude (EVM)
6.5.2.1 A	PUSCH-EVM with exclusion period
6.5.2.2	Carrier leakage
6.5.2.3	In-band emissions for non allocated RB
6.5.2.4	EVM Equalizer spectrum flatness
6.6.1	Occupied bandwidth
6.6.2.1	Spectrum Emission Mask
6.6.2.2	Additional Spectrum Emission Mask
6.6.2.3	Adjacent Channel Leakage power Ratio
6.6.3.1	Transmitter Spurious emissions
6.6.3.2	Spurious emission band UE co-existence
6.6.3.3	Additional spurious emissions
6.7	Transmit intermodulation

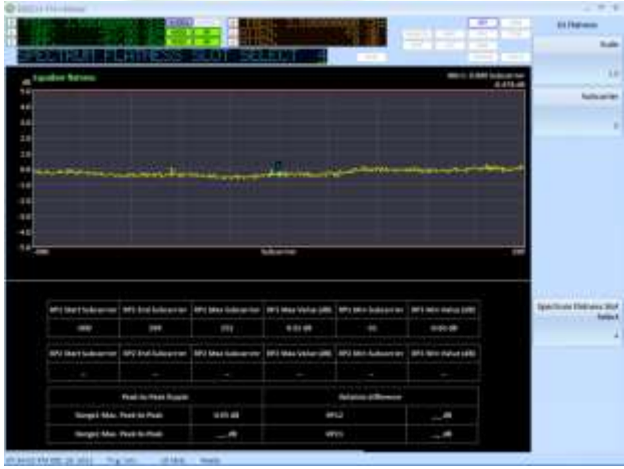
UL RF Measurements



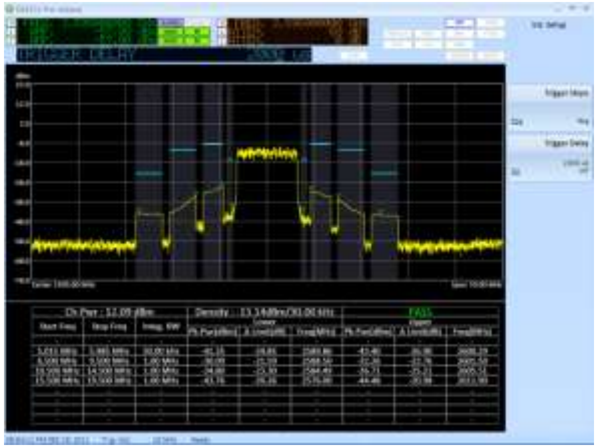
Constellation



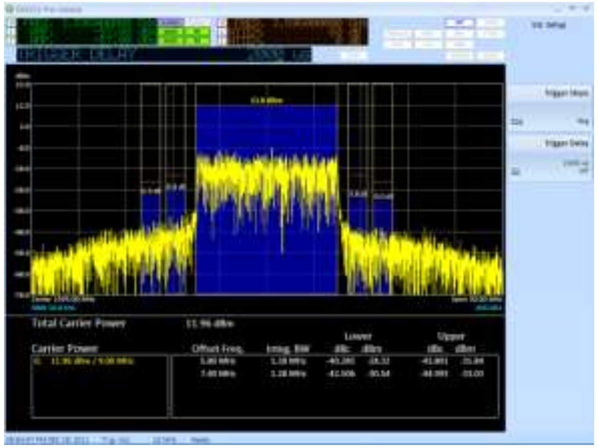
Channel Power



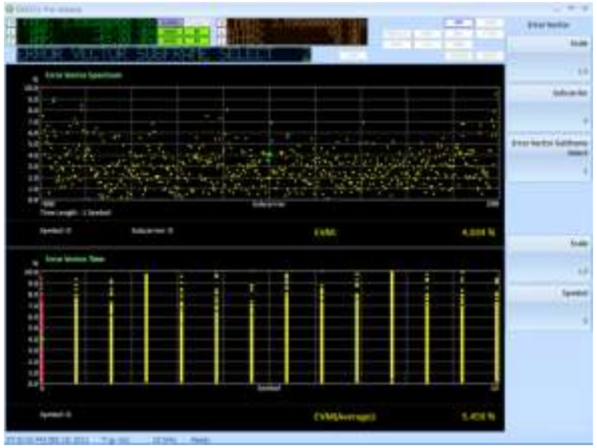
Sub-carrier flatness



SEM



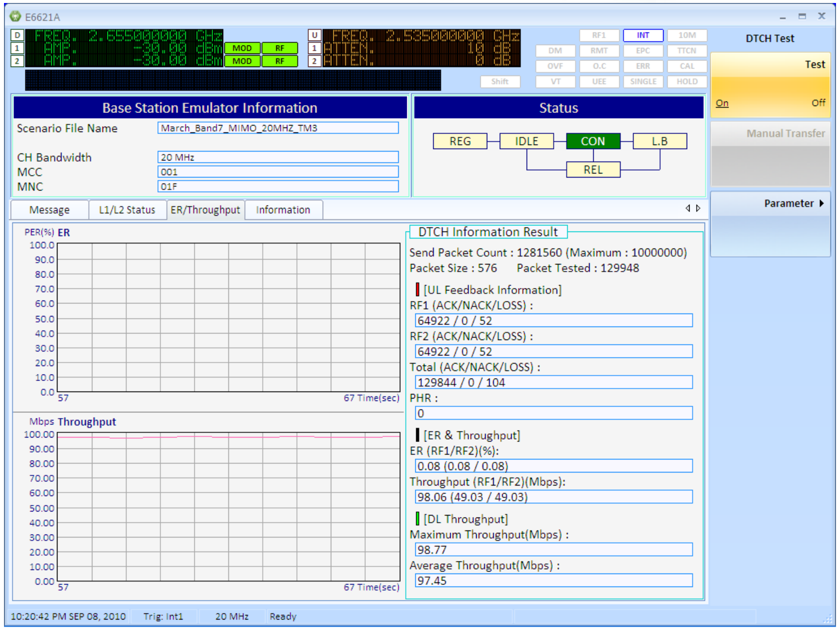
ACLR



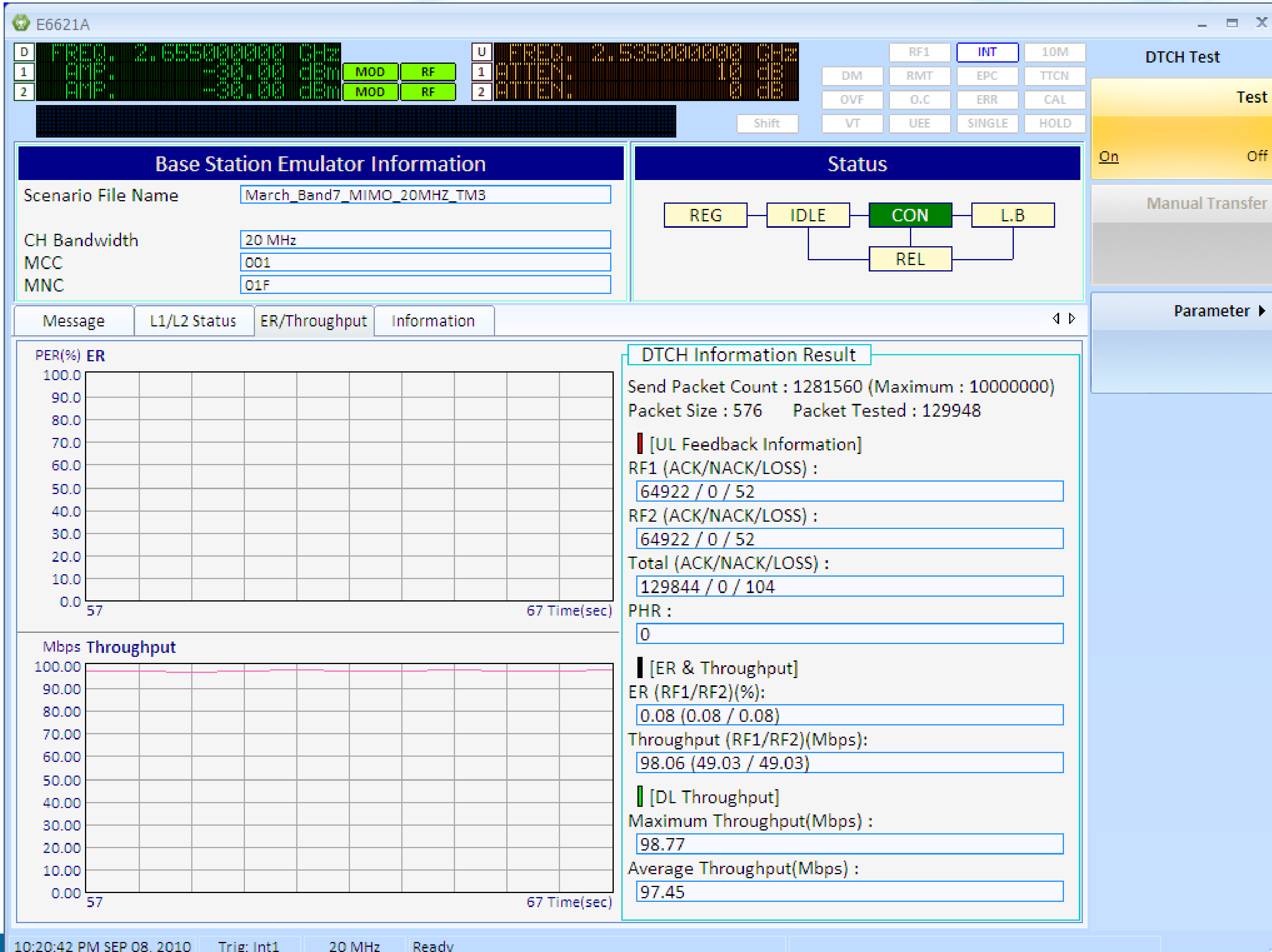
EVM vs symbol

3. Do I have a good quality receiver?

- High Data throughput testing relies on good a quality receiver
- Look for the following:-
  - sensitivity for different modulation schemes
  - Max input level performance
  - susceptibility to interference (simultaneous UL/DL, other radios, spurs from digital board, …)



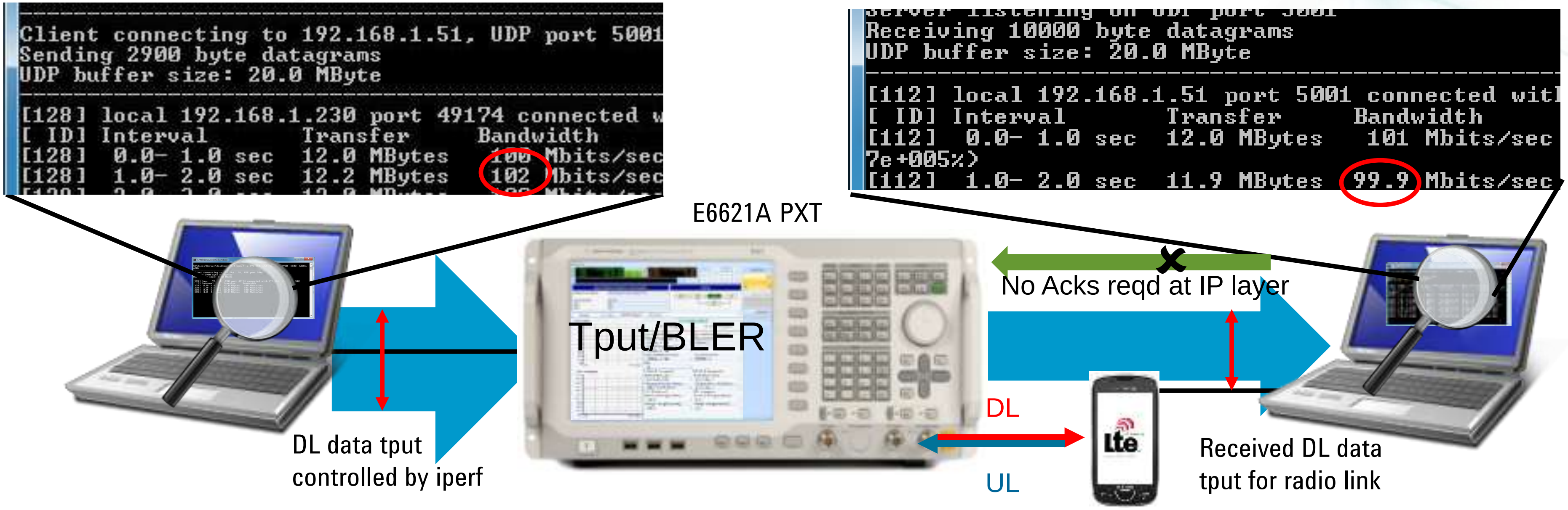
3. Do I have a good quality receiver?



Rx Measurements

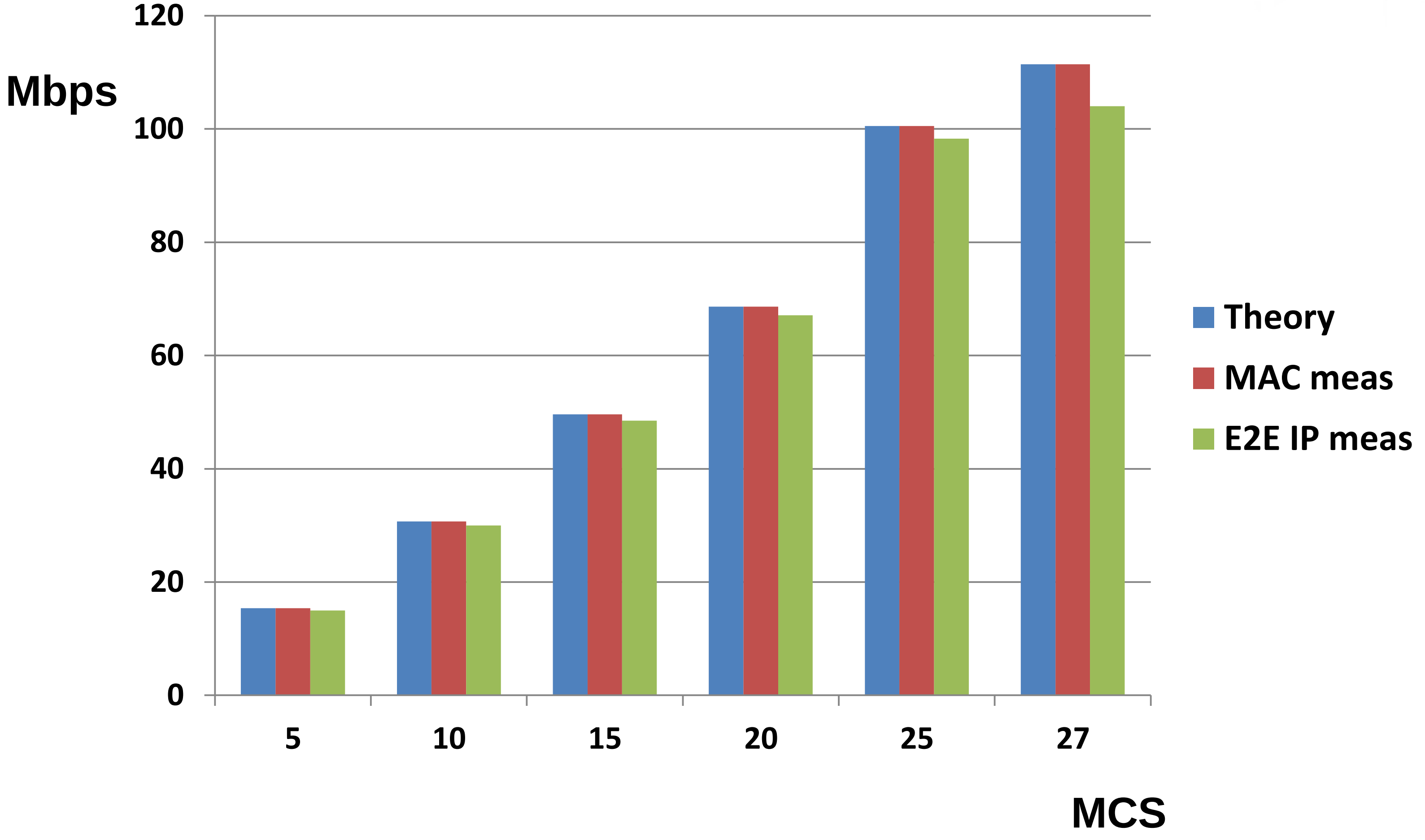
Section 7 Receiver Characteristics					Requires SS	Requires SA
7.3	Reference sensitivity level	Supported	Yes	Yes		
7.4	Maximum input level	Supported	Yes	Yes		
7.5	Adjacent Channel Selectivity (ACS)	Supported	Yes	Yes	Y	
7.6.1	In-band blocking	Supported	Yes	Yes	Y	
7.6.2	Out-of-band blocking	Supported	Yes	Yes	Y	
7.6.3	Narrow band blocking	Supported	Yes	Yes	Y	
7.7	Spurious response	Supported	Yes	Yes	Y	
7.8.1	Wideband intermodulation	Supported	Yes	Yes	Y x 2	
7.9	Spurious emissions	Supported	Yes	Yes		Y

4. Can I achieve max E2E Tput under ideal conditions with UDP?



- iperf used to provide UDP data stream and measure received throughput
- No IP level ACKs required
- Measure results vs modulation/coding scheme
- Fluctuating BLER may indicate RF issues
- Sudden loss of data may indicate memory loss issues

DL Data Throughput for TD LTE
(20MHz channel, 2x2 MIMO, UL/DL config 5, special subframe config 6)



Measurement Technique: UDP vs FTP (TCP)

UDP

+ Unacknowledged
+ removes flow control complexity
+ removes higher layer acks
+ Less susceptible latency

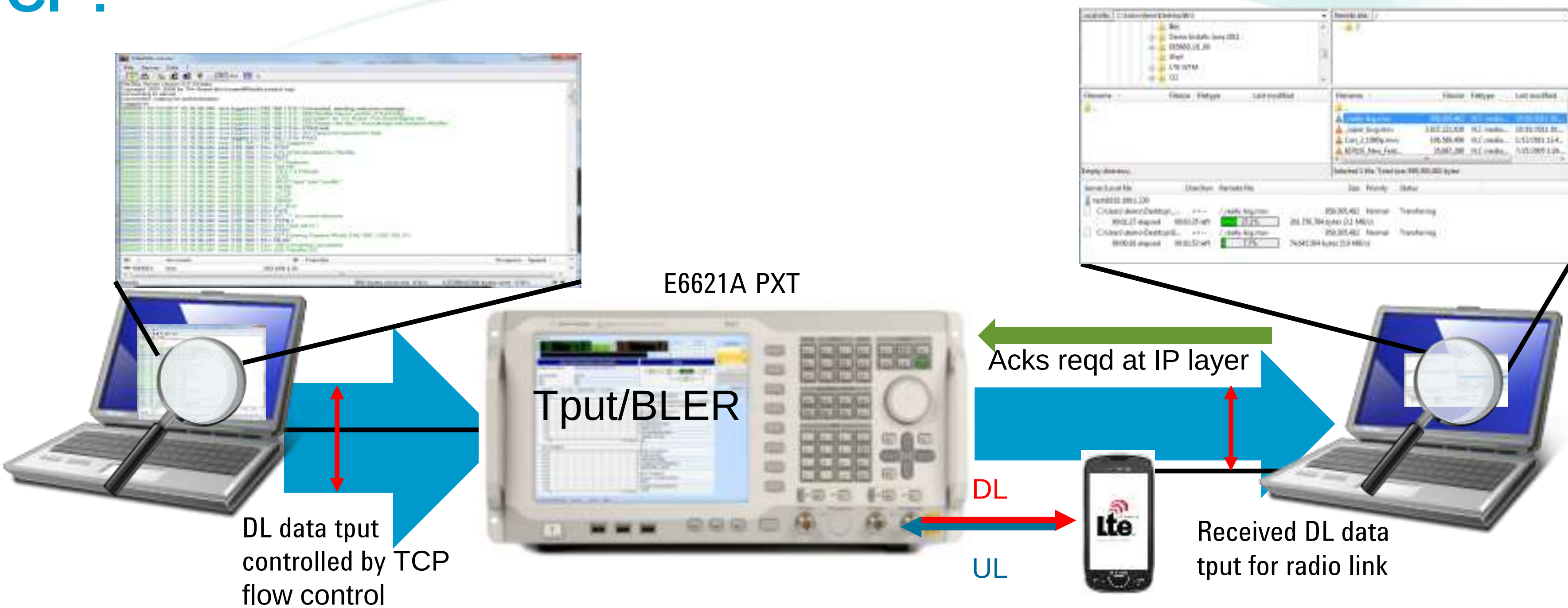
- Not the full story for file transfers
- Not suitable for used in shared networks

FTP

+ Simulates real-world file transfers
+ Transferred files can be viewed and/or compared

- Adds flow control complexity
- Add higher layer acks and re-transmissions
- TCP Control algorithms sensitive to multiple parameters
- Test system configuration can affect results

5. Can I achieve max E2E tput under ideal conditions with TCP?



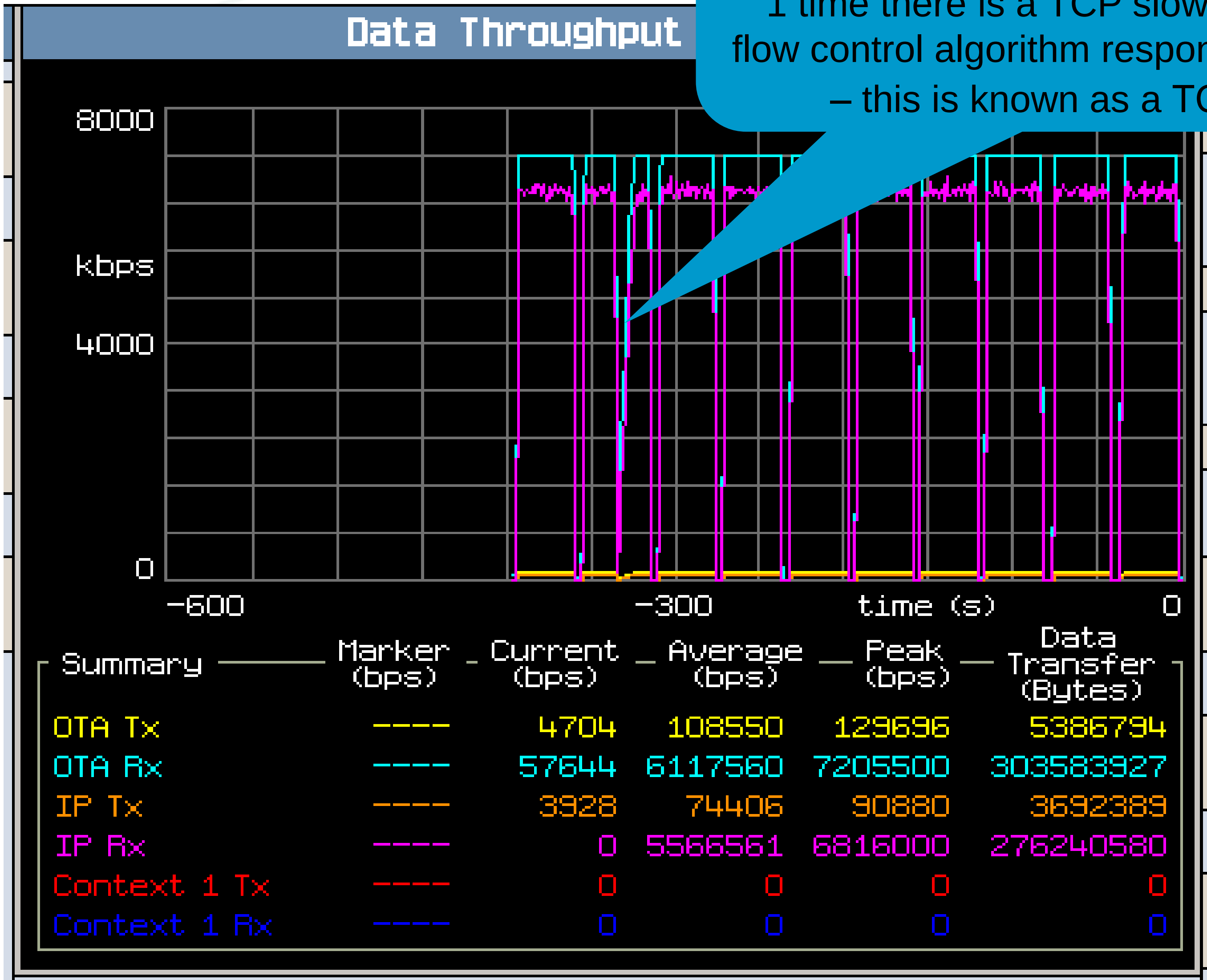
- TCP adds higher layer support for error detection, re-transmissions, congestion control and flow control
- TCP flow control algorithms interpret “lost” packets as congestion
- Careful consideration of parameters such as window size, number of parallel process, segment size etc. need to be considered

TCP “Flapping”

The same file FTP’d 10 times.

9 times rate is flat and consistent.

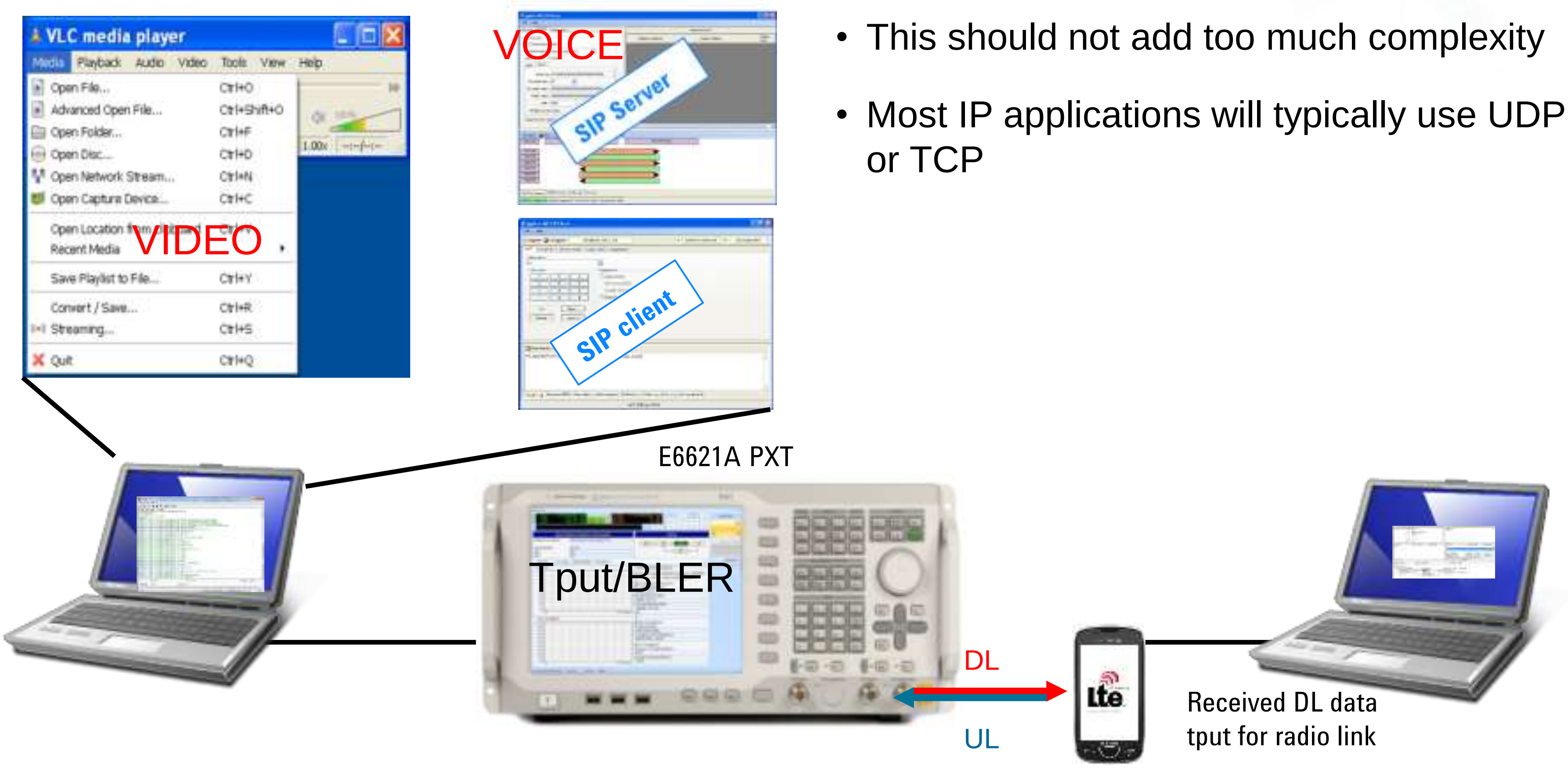
1 time there is a TCP slow-start as the flow control algorithm responds to an error – this is known as a TCP “flap”



Summary	Marker (bps)	Current (bps)	Average (bps)	Peak (bps)	Data Transfer (Bytes)
OTA Tx	-----	4704	108550	129696	5386794
OTA Rx	-----	57644	6117560	7205500	303583927
IP Tx	-----	3928	74406	90880	3692389
IP Rx	-----	0	5566561	6816000	276240580
Context 1 Tx	-----	0	0	0	0
Context 1 Rx	-----	0	0	0	0

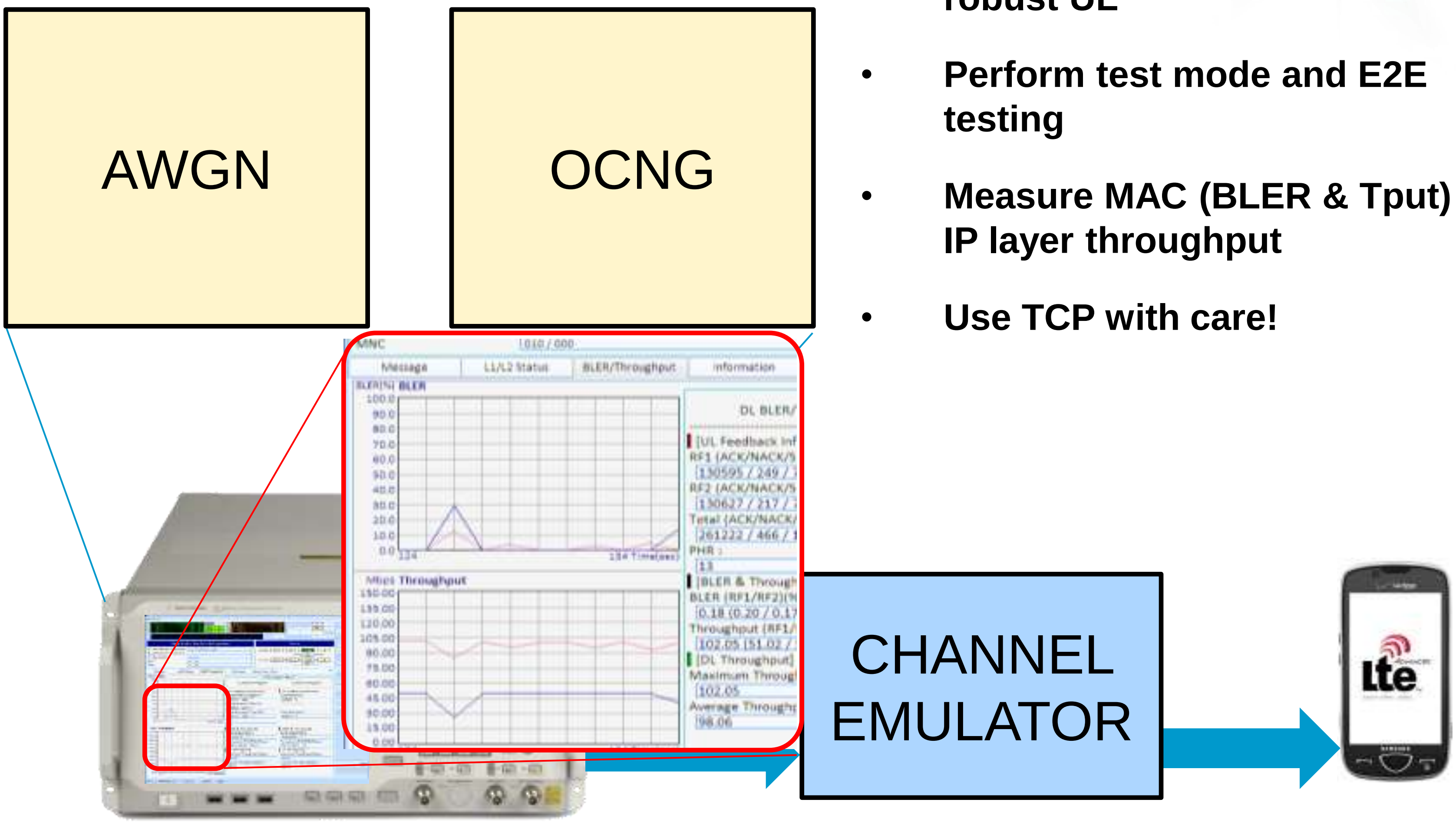
6. What happens if I try a real application? … (Voice, video, ftp …)

- This should not add too much complexity
- Most IP applications will typically use UDP or TCP

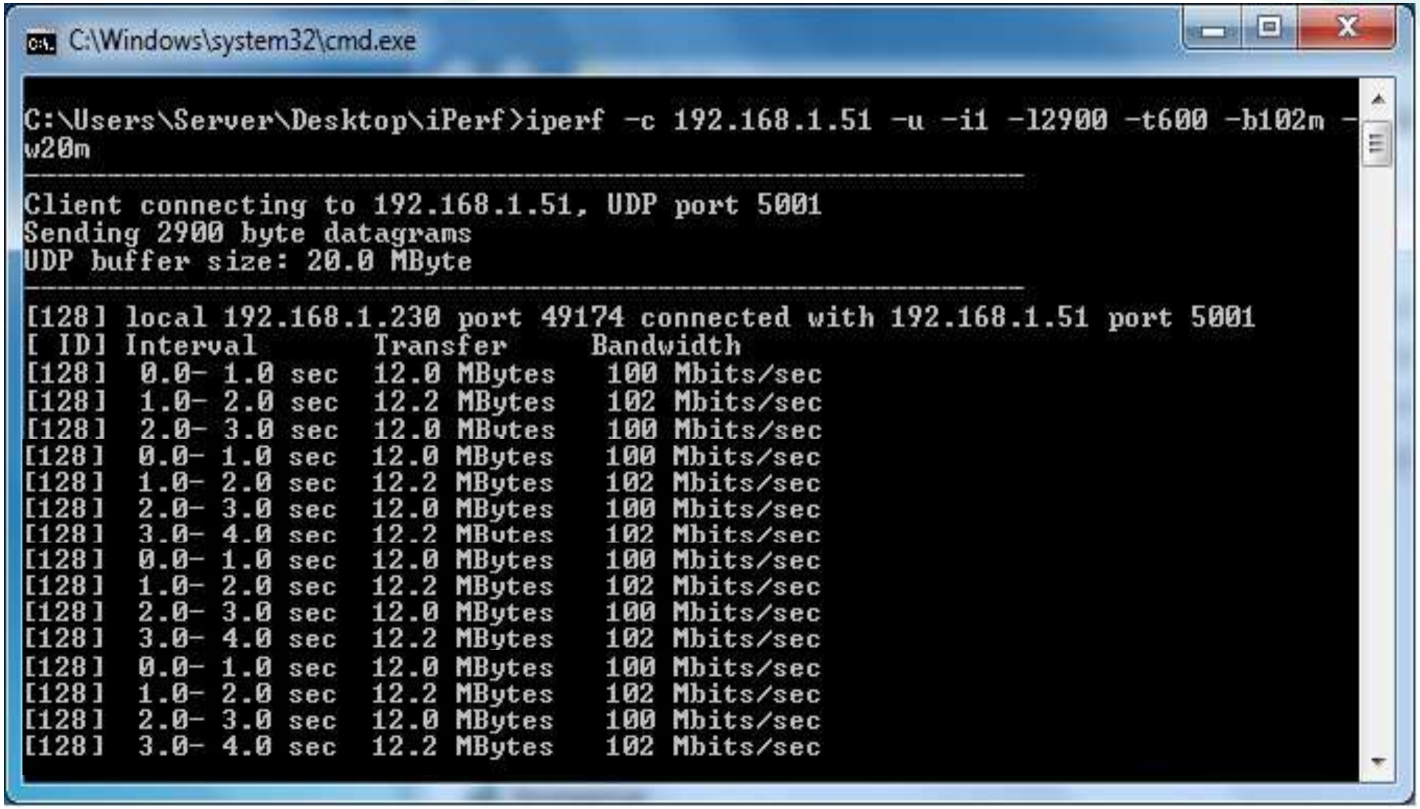


7. What happens under non-ideal conditions?

- **Typically fade the DL and use robust UL**
- **Perform test mode and E2E testing**
- **Measure MAC (BLER & Tput) and IP layer throughput**
- **Use TCP with care!**

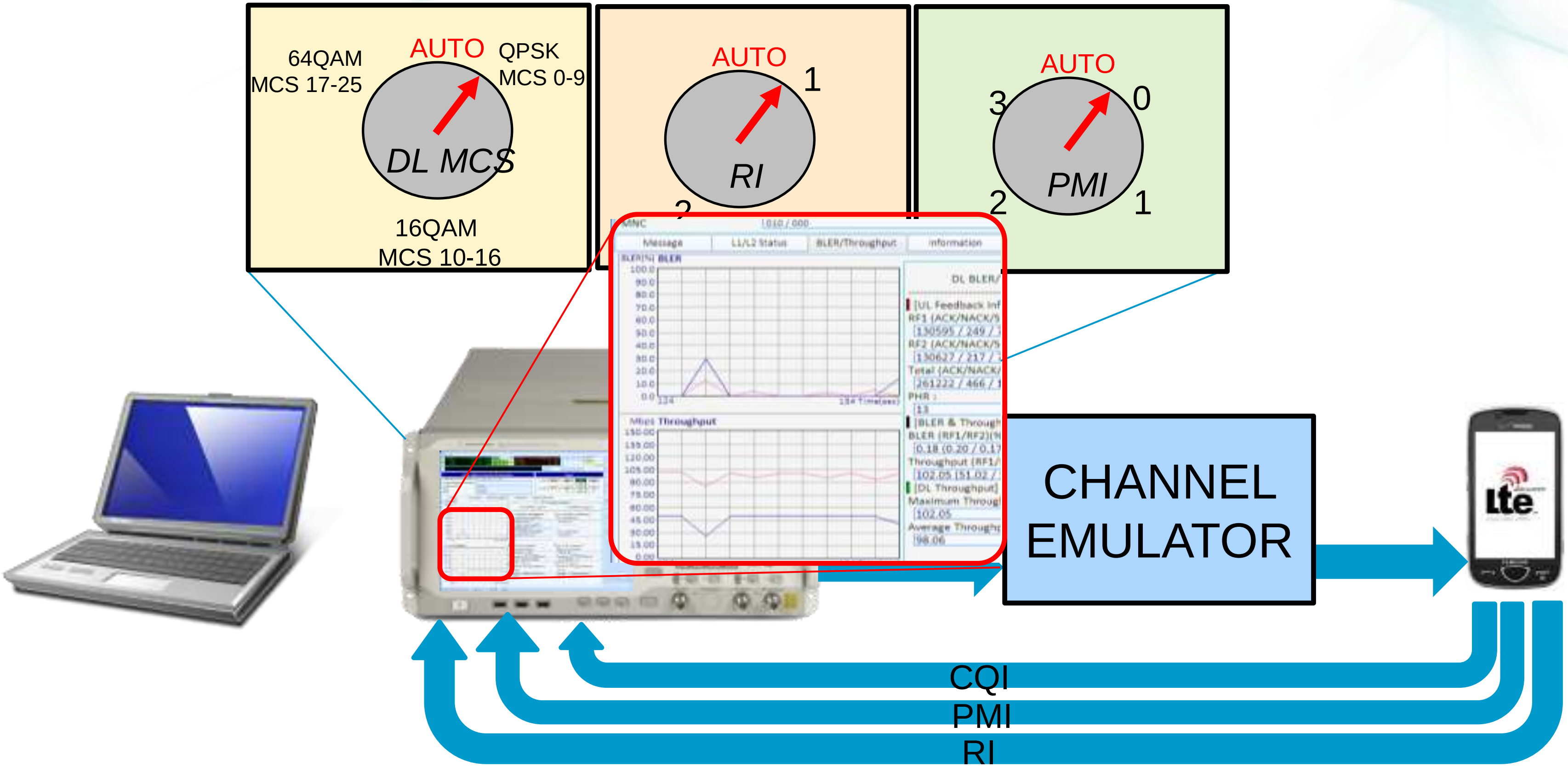


8. Is it robust? …



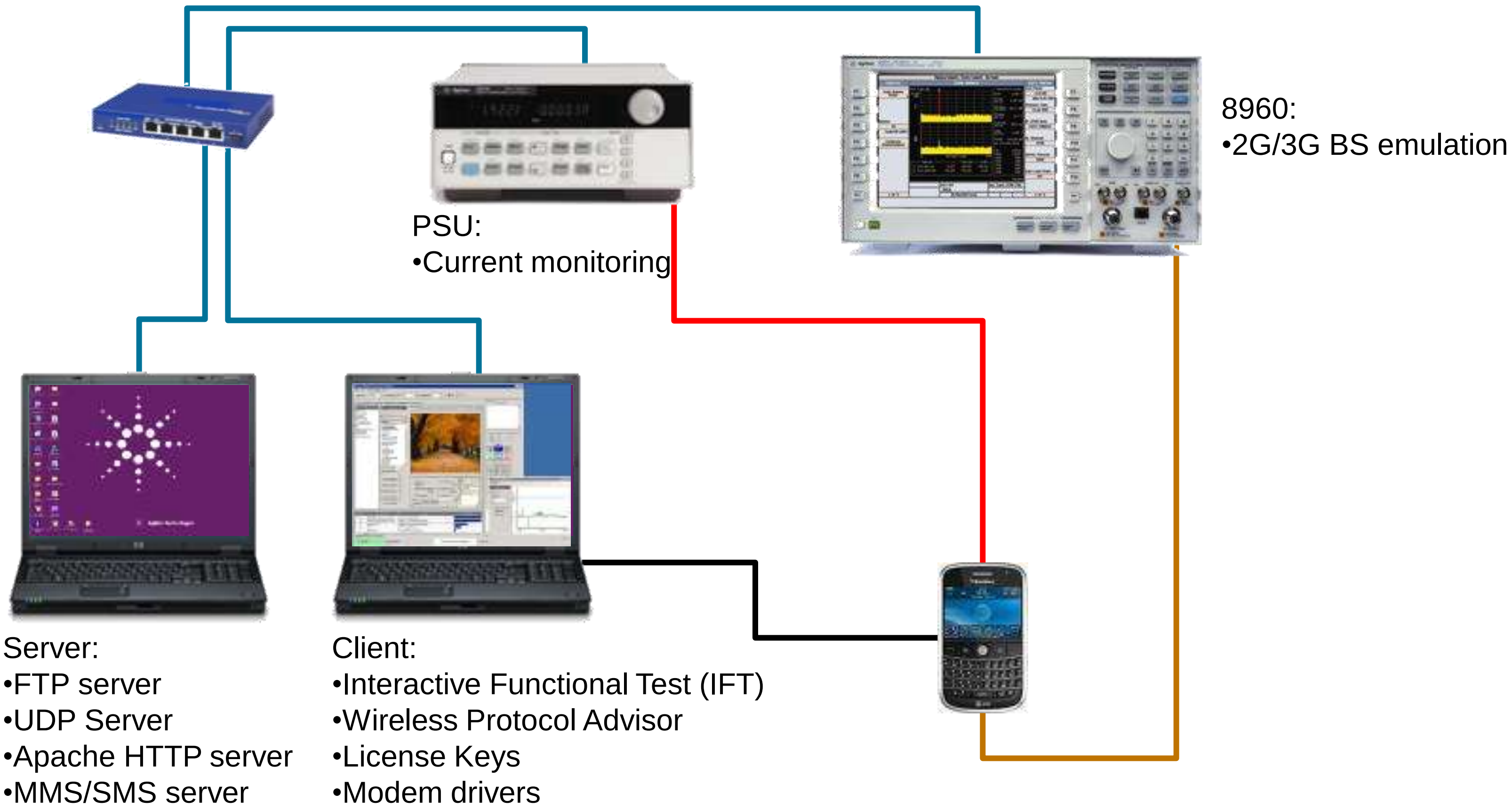
- **E2E IP tests PHY, MAC, PDCP, and IP layers all working together at full rate**
- Check processor can handle multiple real time activities – add SMS and voice calls during E2E IP
- **Check there are no memory overflow/leakage issues**

9. Does it work closed loop?



- **BLER/Tput Testing**
- **Supports Test Mode and E2E Testing**

10. How good is my battery life?



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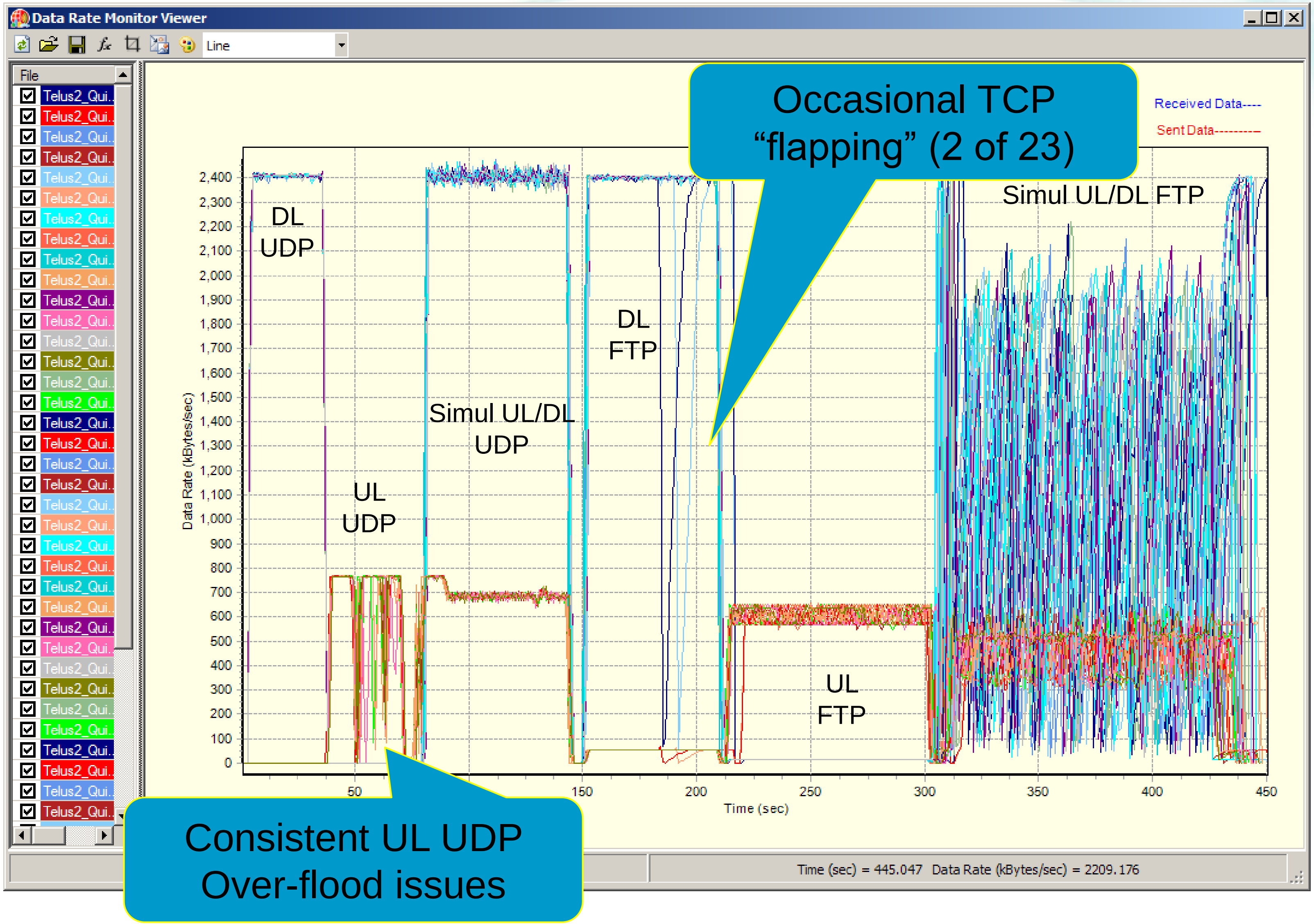
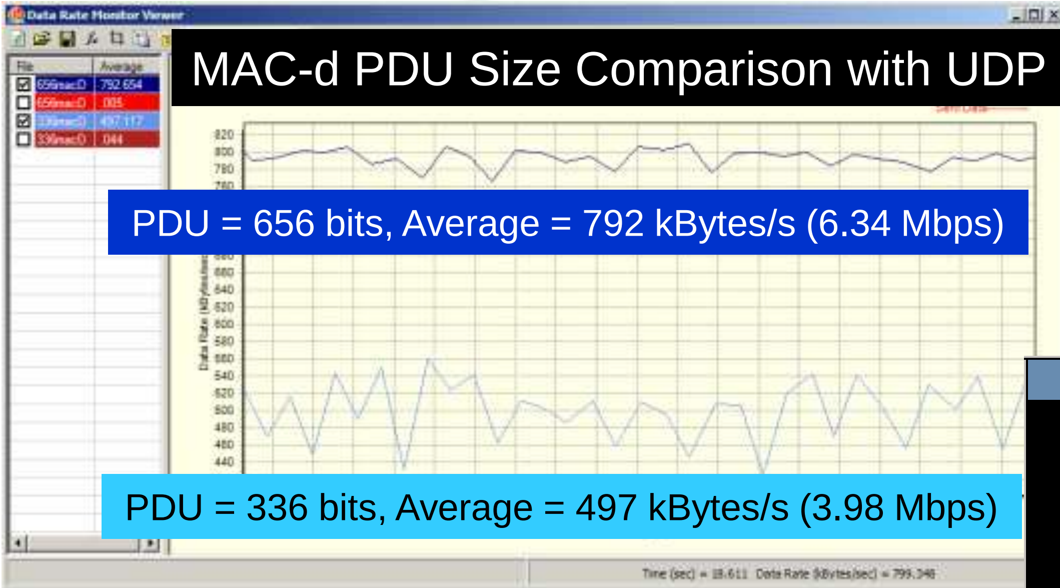
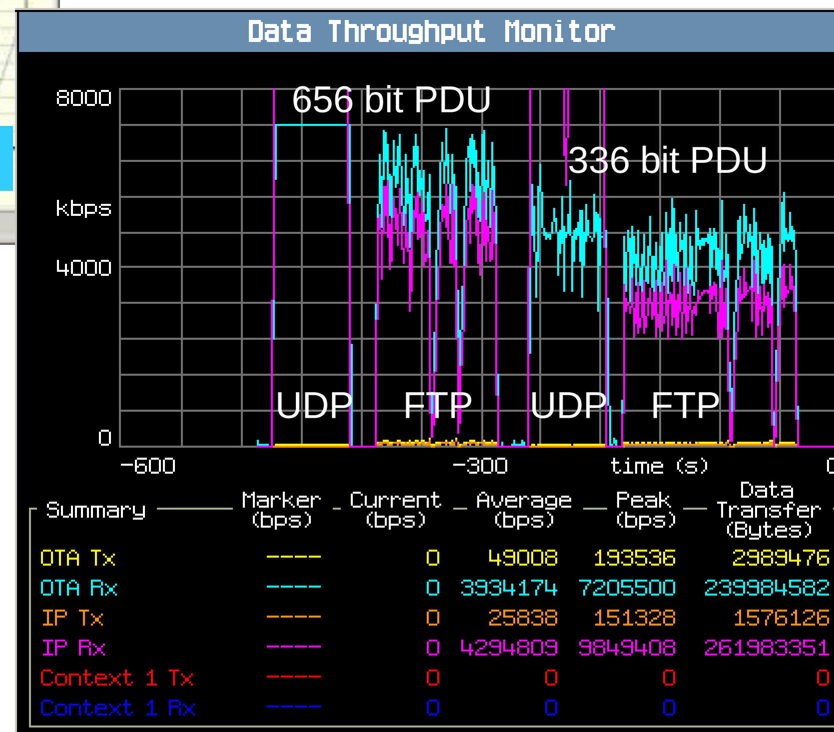
Automated Measurements Give Repeatable 21Mbps Results!



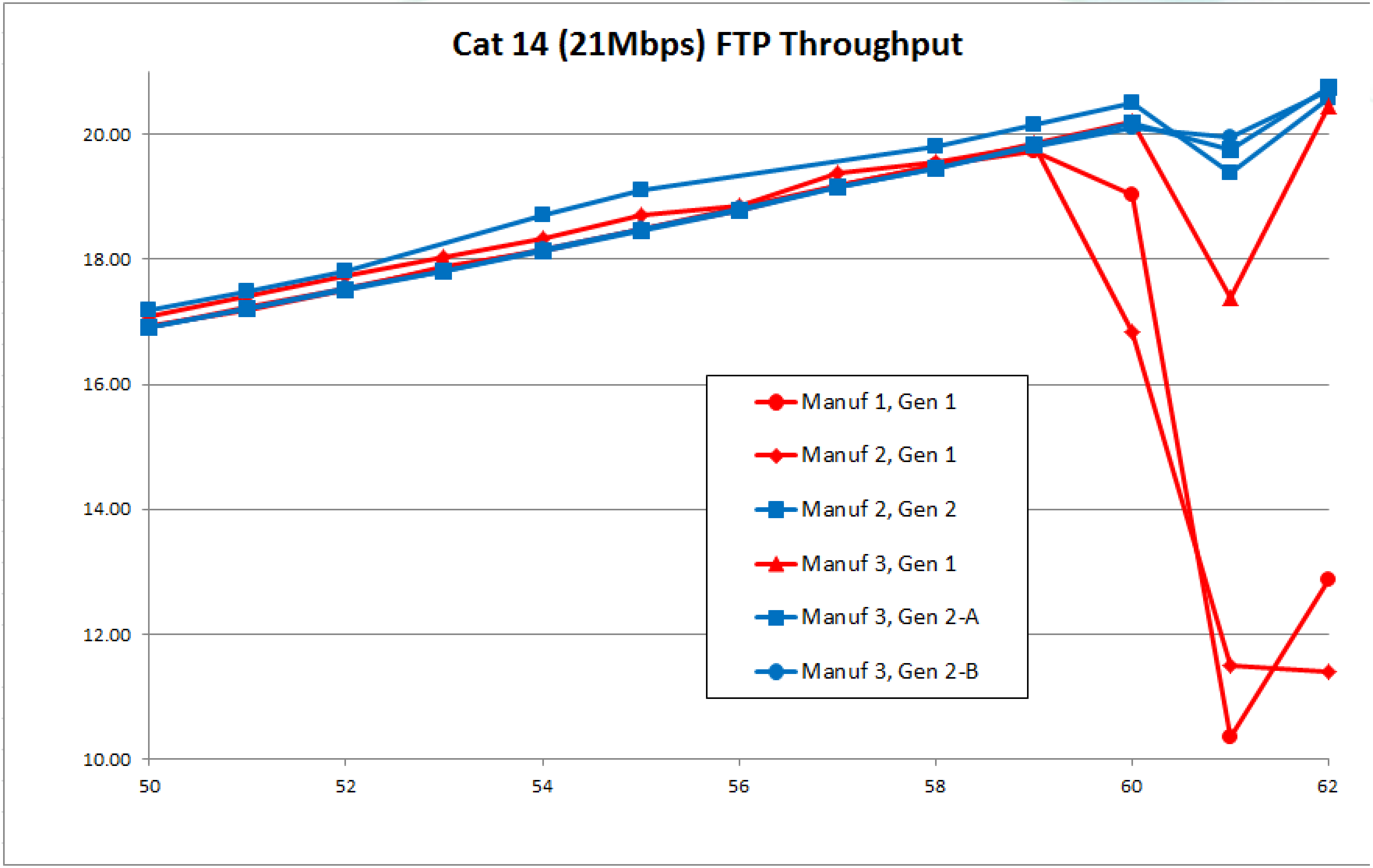
Device Performance: MIPS Matter!





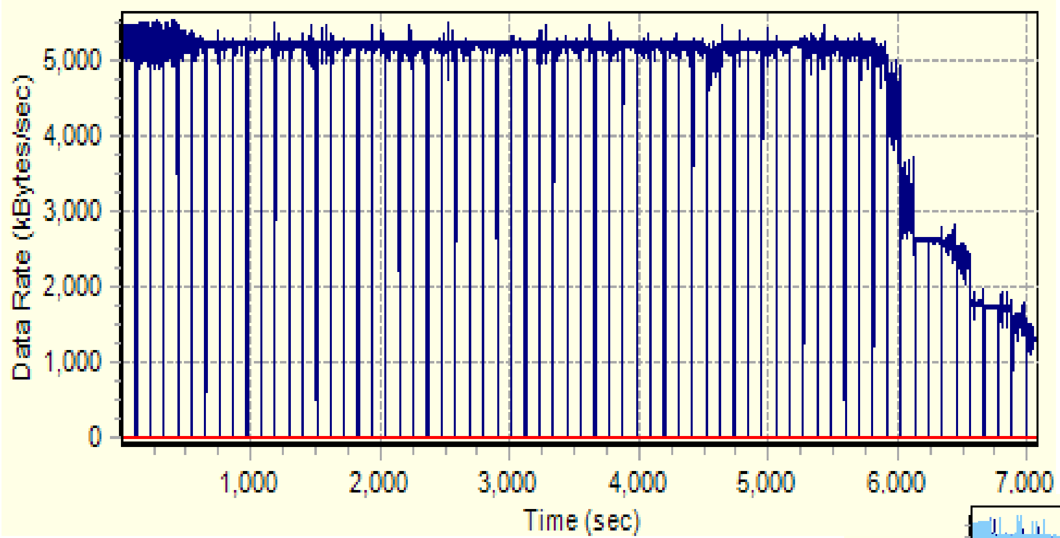
This comparison was made with a very early Cat 8 HSDPA phone. When the MAC-d block size is smaller, the device doesn't have the MIPS to sustain the high rate.

Cat14 (21Mbps) Devices – Better the second time around

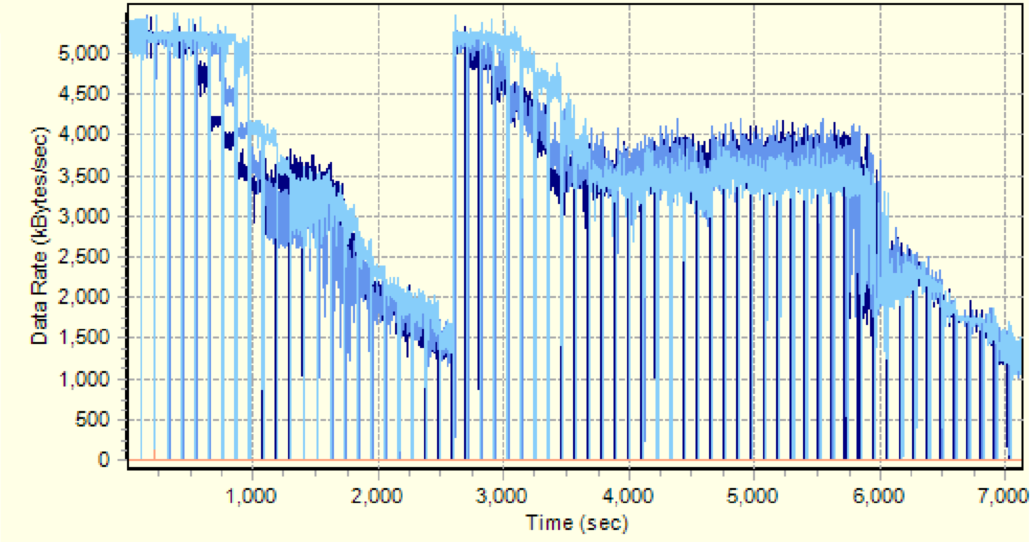


Dual-Carrier HSDPA (42Mbps) – Diversity Matters!

Throughput for Rx Power = -20dBm to -85dBm



2nd RF Connector terminated (or connected via a splitter)



Same device with 2nd RF connector left "floating"

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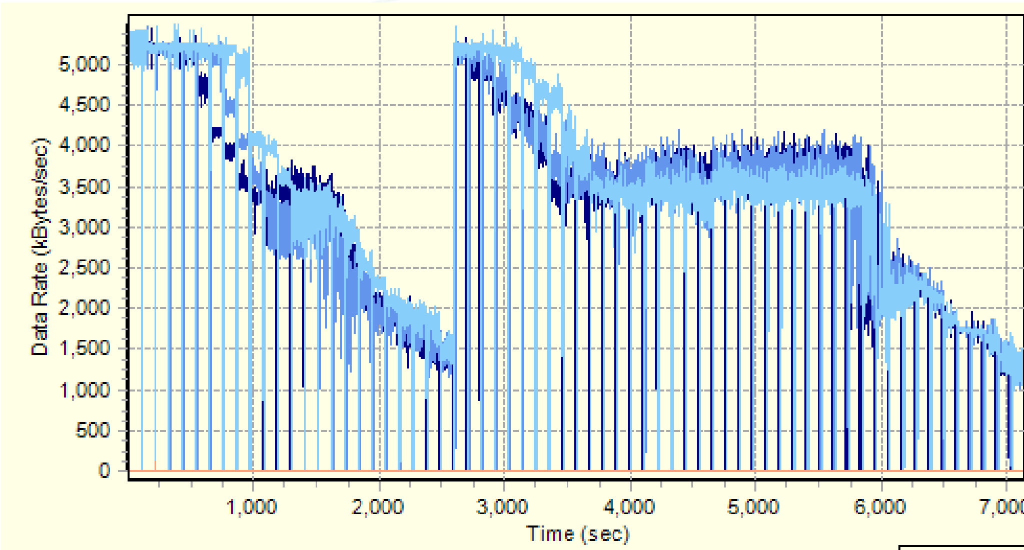
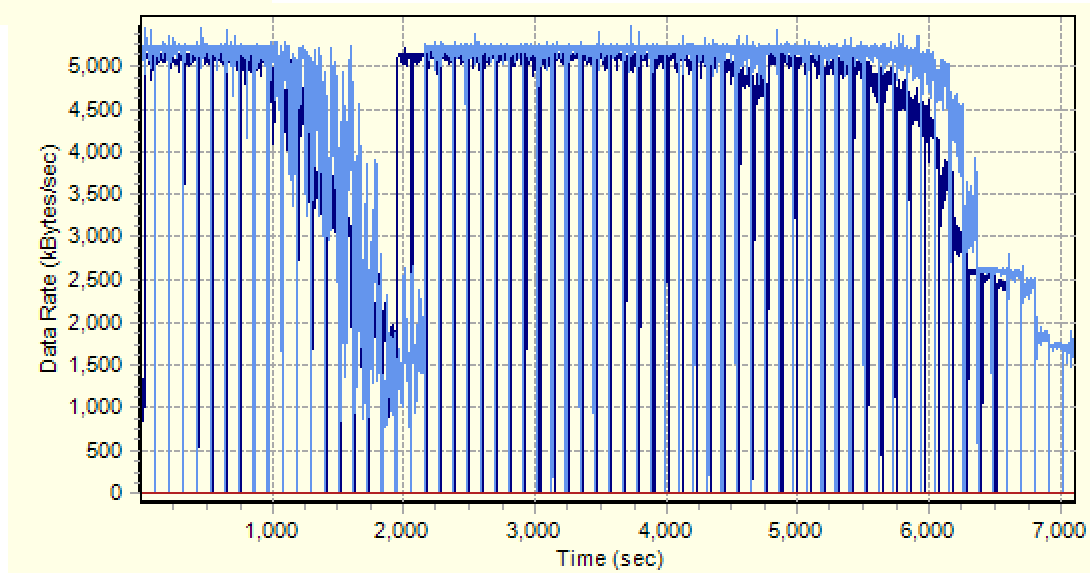
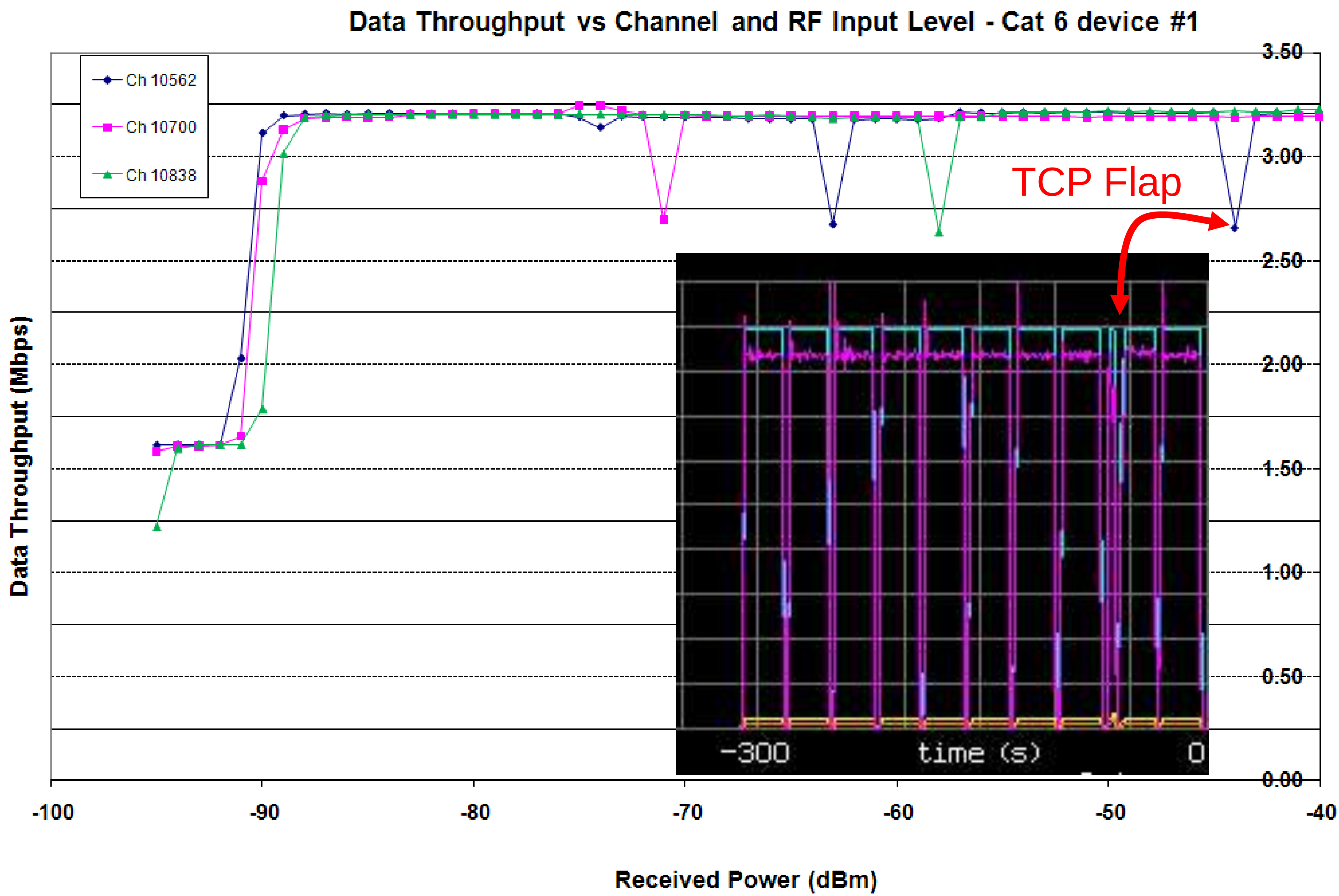


Same device with 2nd RF connector left “floating”

Device with only 1 RF connector available



Not All HSDPA Cat 6 Devices Have the Same Throughput



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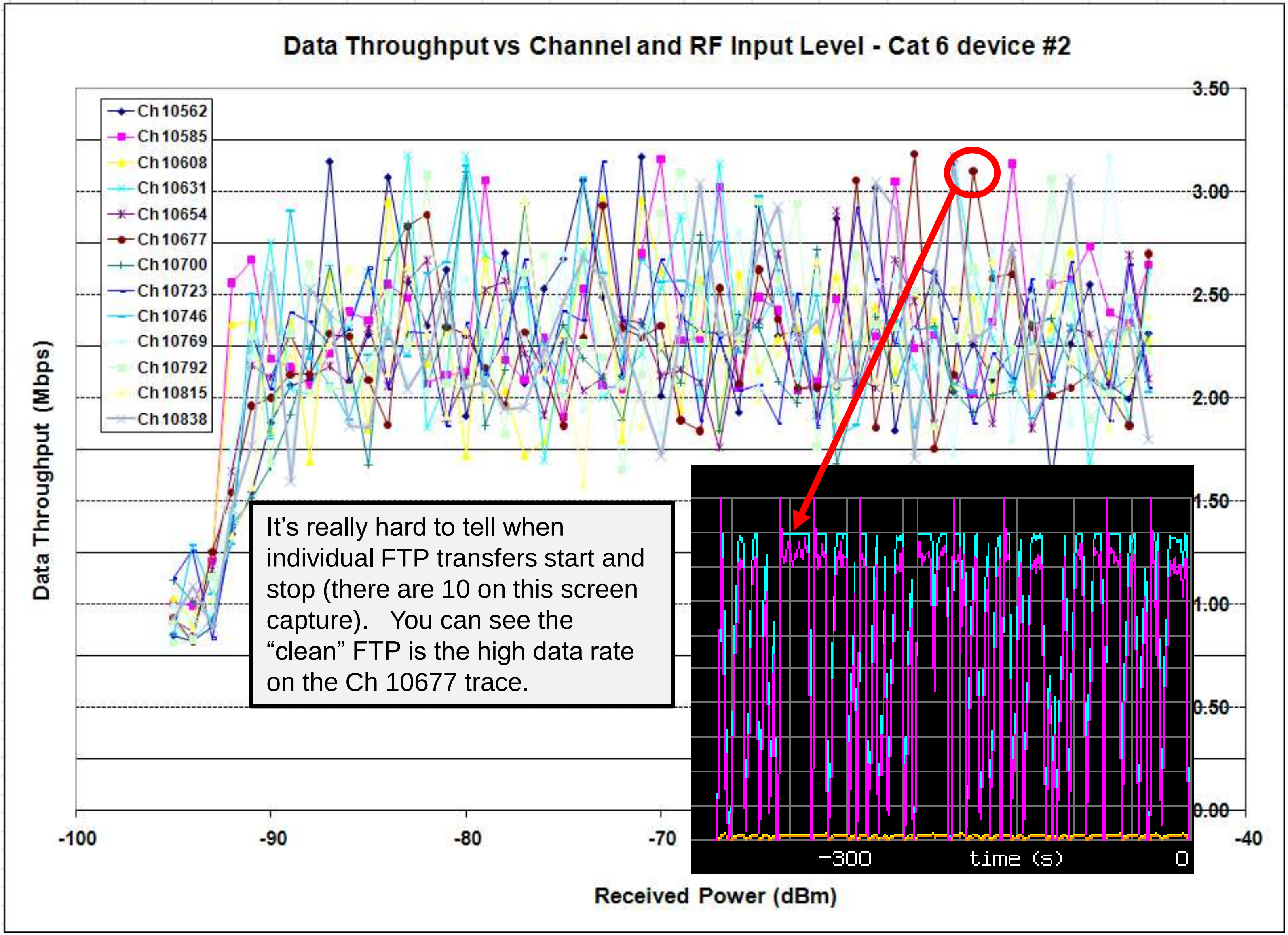

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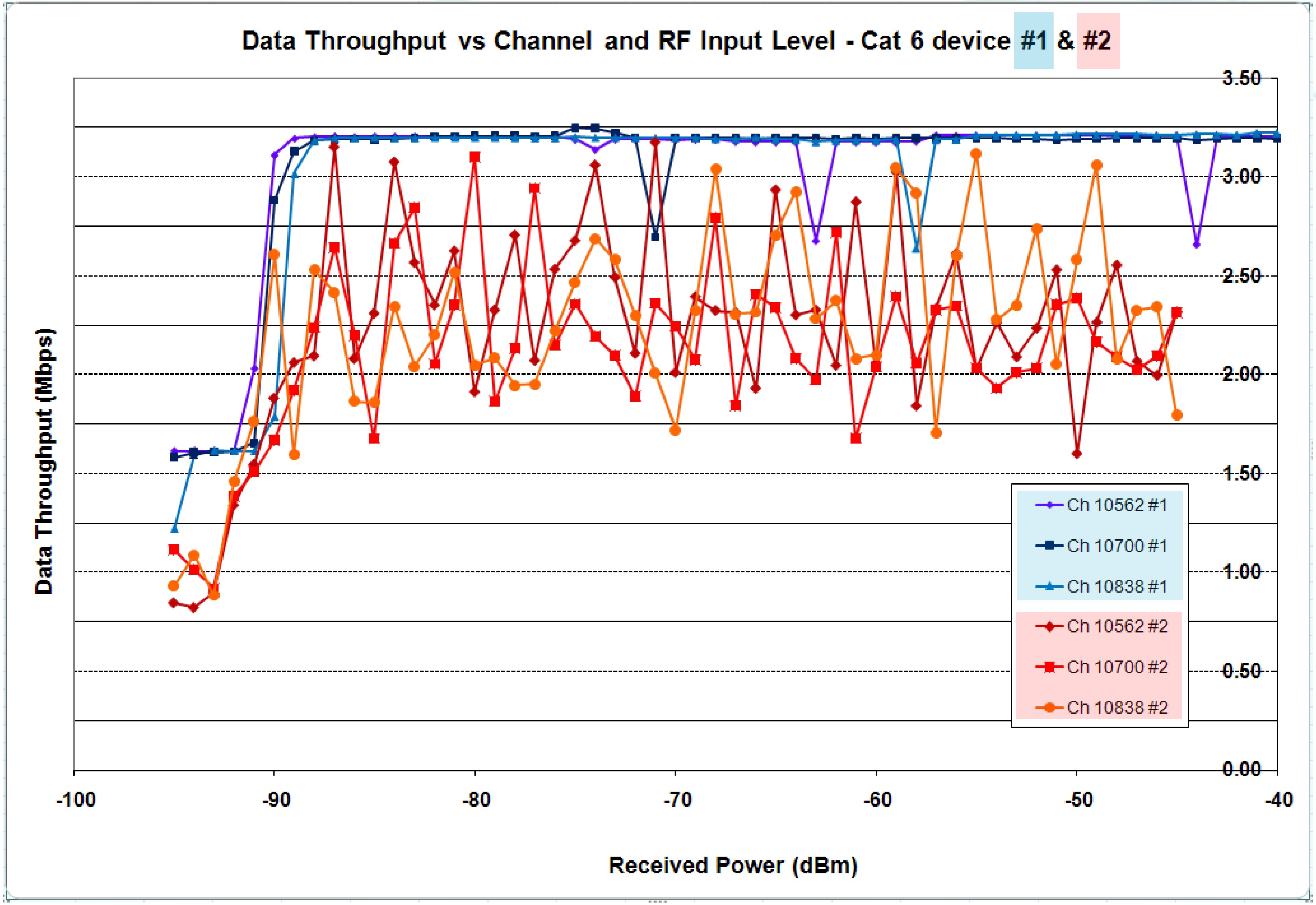
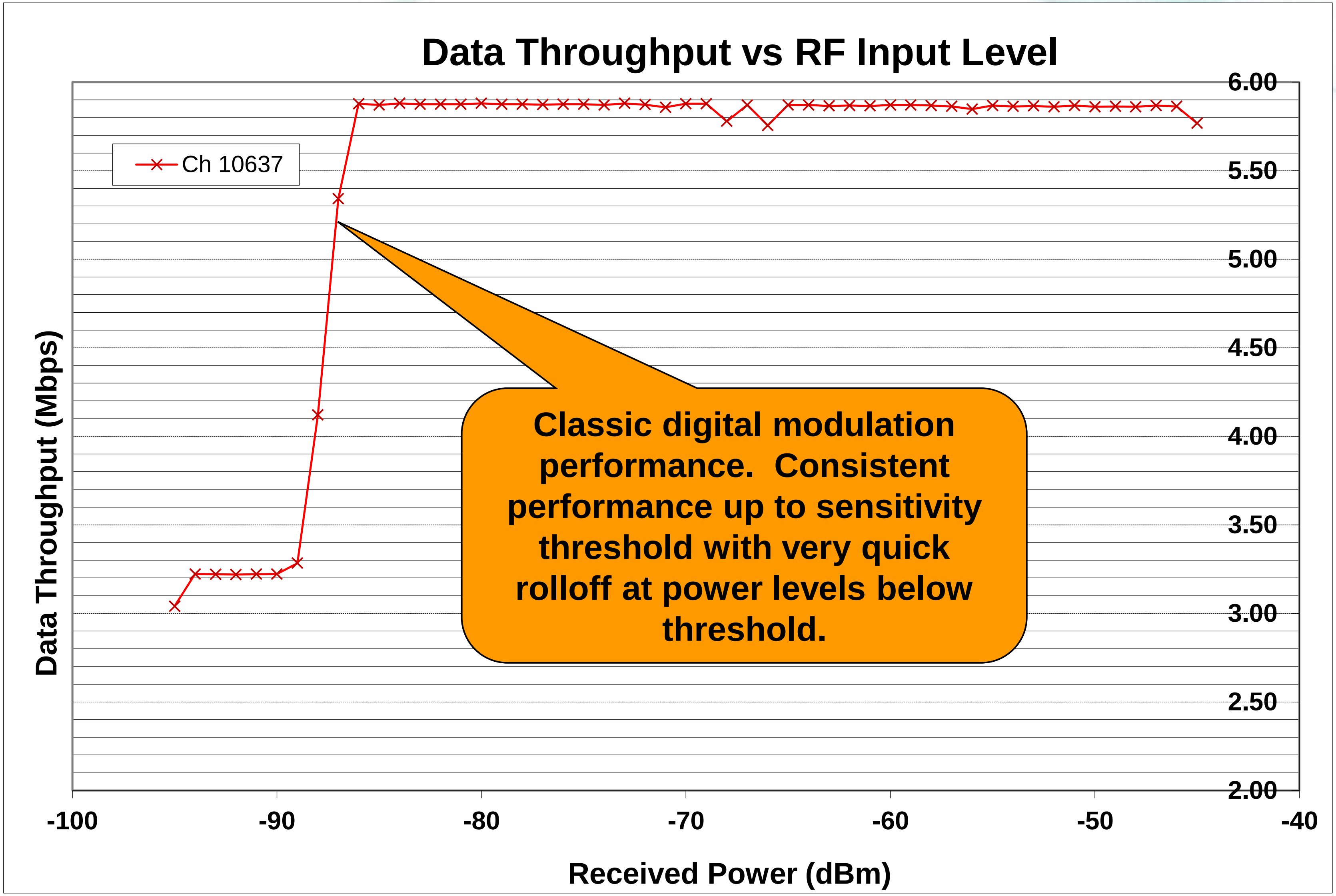


Data Throughput Across Input Power Level



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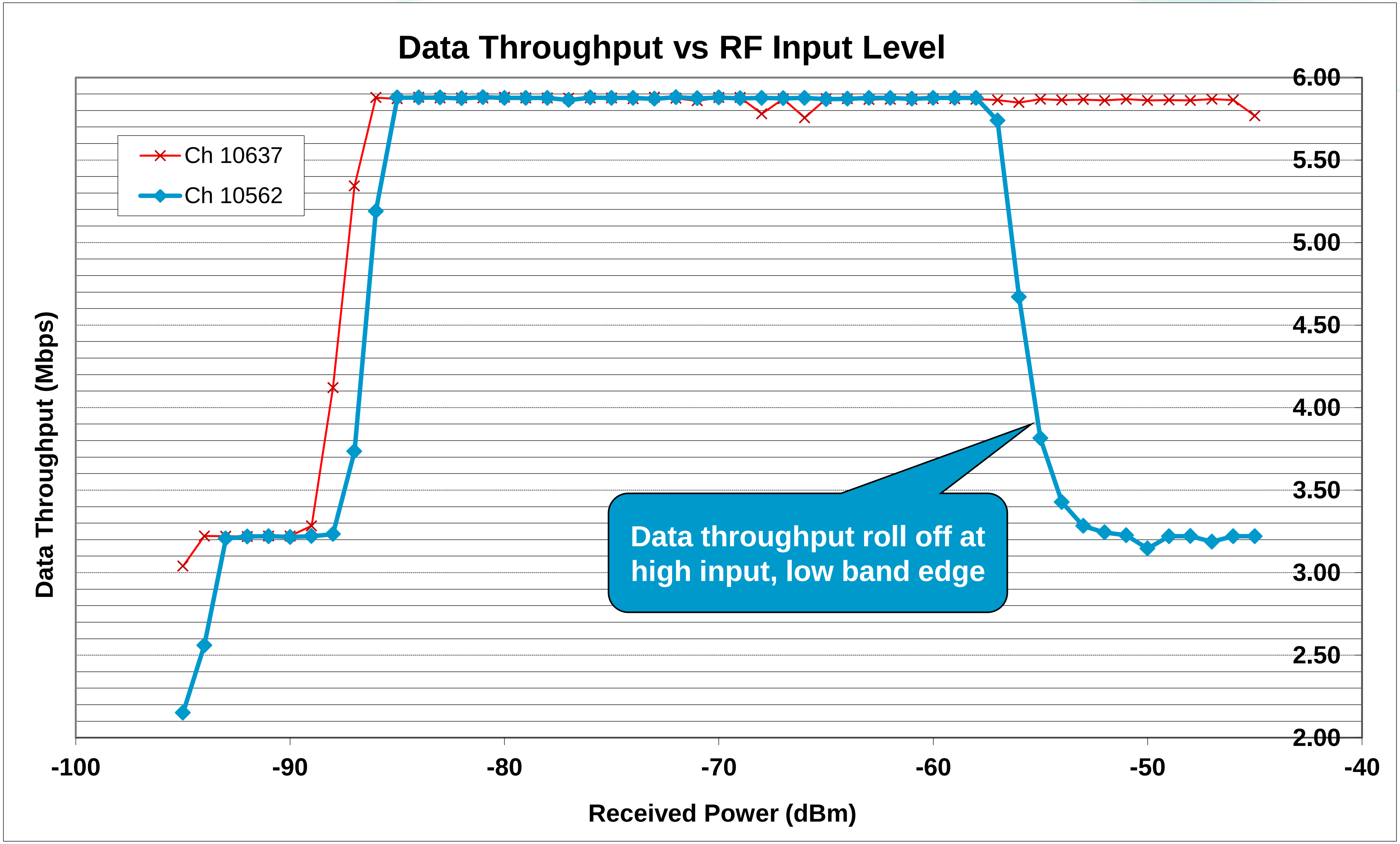

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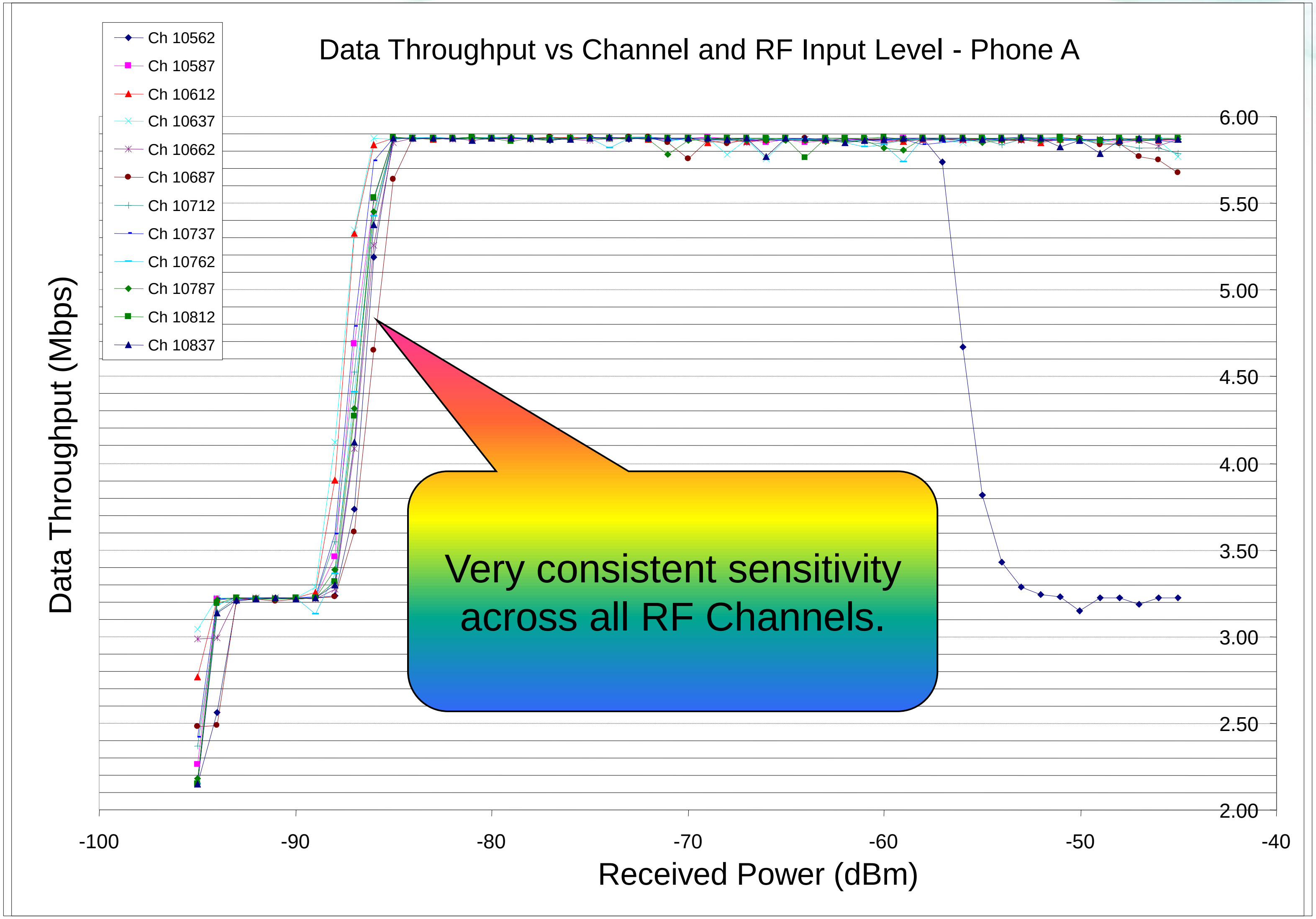
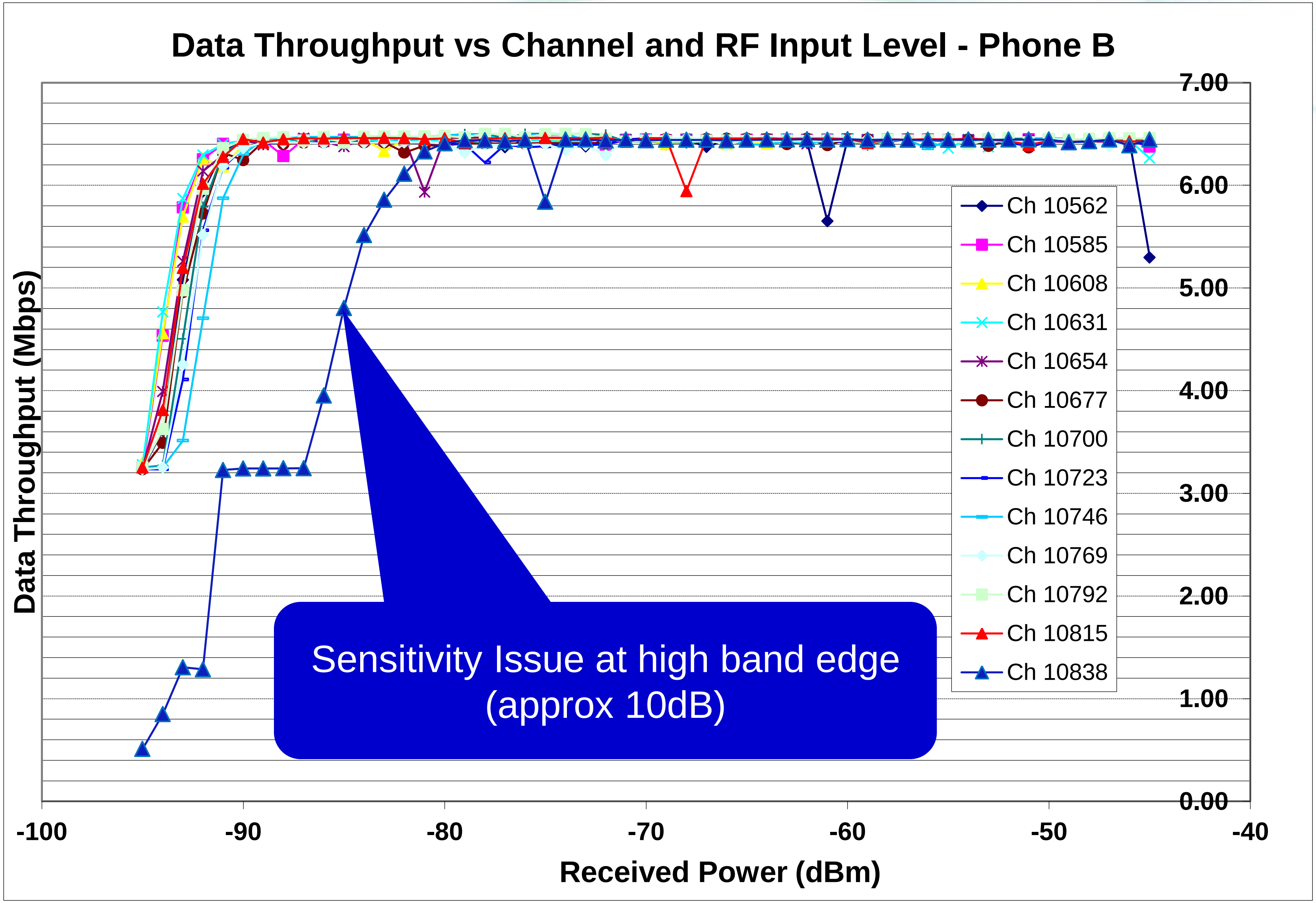
Data Throughput Across Channels and RF Input Levels



Data Throughput Across Channels and RF Input Levels



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- **E2E IP Data throughput is a very useful measurement which stress tests the device against a key specification**
- **The measurement is good for finding problems**
- **Troubleshooting the problem requires you to peel back the onion**
- **We have looked at examples of E2E IP issues found testing 3G/4G commercial UEs**