3GPP LTE Standards Update:

Release 11, 12 and Beyond

Technology Leadership Organization

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Agenda

Wireless evolution 1990 – 2012

Deployment update

Summary of Releases 8, 9 and 10 radio aspects

How to navigate 3GPP Releases and work items

Release 11 work items

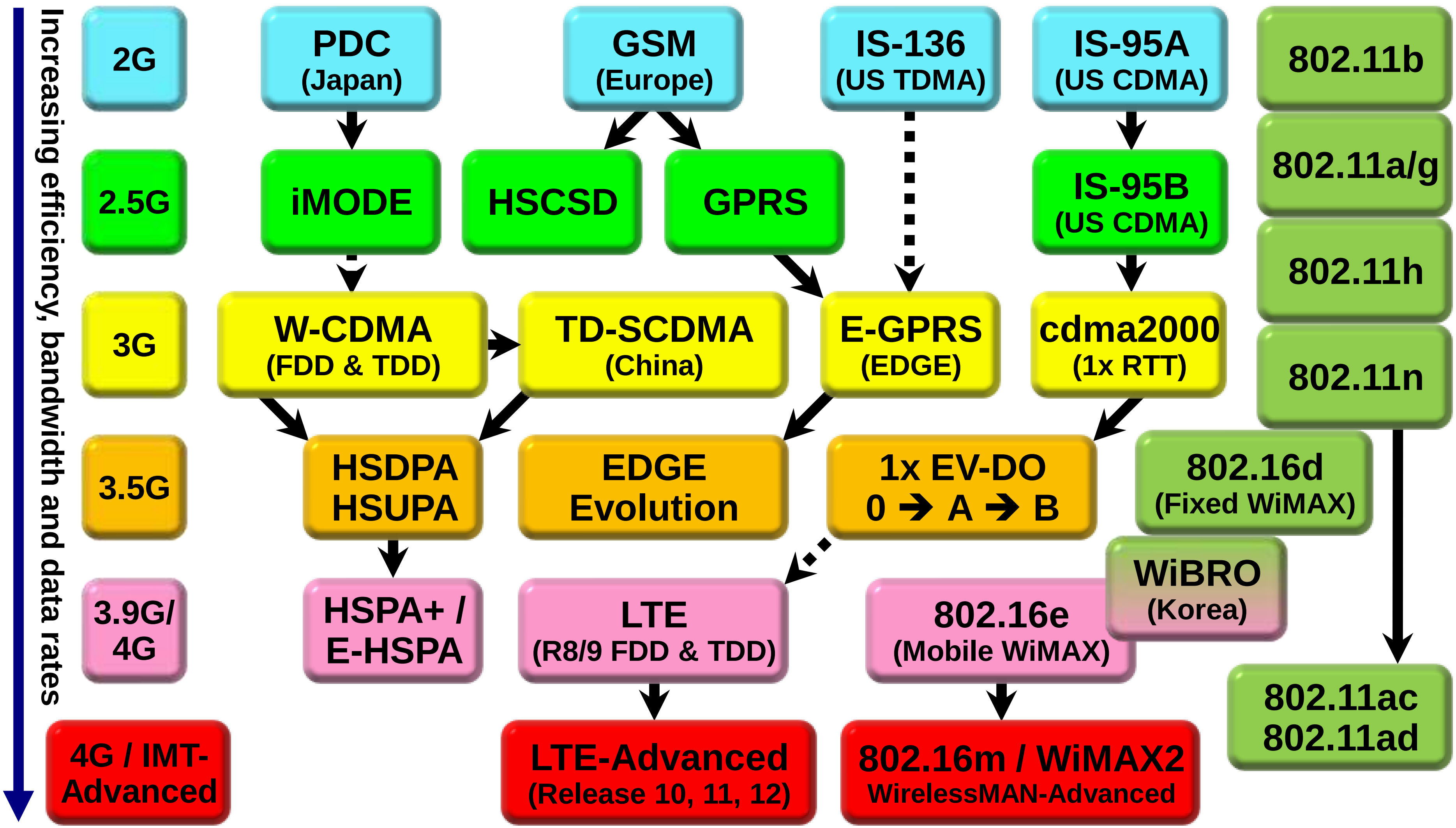
3GPP RAN Release 12 Workshop

Release 12 work items

Release 12 study items

Summary

Wireless evolution 1990 - 2012



UMTS Long Term Evolution

1999 → 2013

Release	Stage 3: Core specs complete	Main feature of Release
Rel-99	March 2000	UMTS 3.84 Mcps (W-CDMA FDD & TDD)
Rel-4	March 2001	1.28 Mcps TDD (aka TD-SCDMA)
Rel-5	June 2002	HSDPA
Rel-6	March 2005	HSUPA (E-DCH)
Rel-7	Dec 2007	HSPA+ (64QAM DL, MIMO, 16QAM UL). LTE & SAE Feasibility Study, Edge Evolution
Rel-8	Dec 2008	LTE Work item – OFDMA air interface SAE Work item – New IP core network UMTS Femtocells, Dual Carrier HSDPA
Rel-9	Dec 2009	Multi-standard Radio (MSR), Dual Carrier HSUPA, Dual Band HSDPA, SON, LTE Femtocells (HeNB) LTE-Advanced feasibility study, MBSFN
Rel-10	March 2011	LTE-Advanced (4G) work item, CoMP Study Four carrier HSDPA
Rel-11	Sept 2012	CoMP, eDL MIMO, eCA, MIMO OTA, HSUPA TxD & 64QAM MIMO, HSDPA 8C & 4x4 MIMO, MB MSR
Rel-12	March 2013 stage 1	New carrier type, LTE-Direct, Active Antenna Systems

Understanding 3GPP Releases

The official scope of each 3GPP release is documented at:
www.3gpp.org/releases

Each release comprises a set of work items with three main development stages

- Stage 1: Service description from a service-user's point of view.
- Stage 2: Logical analysis, breaking the problem down into functional elements and the information flows amongst them across reference points between functional entities.
- Stage 3: is the concrete implementation of the protocols appearing at physical interfaces between physical elements onto which the functional elements have been mapped.

And some less formal stages

- Stage 0: Used to describe 3GPP feasibility studies (study items)
- Stage 4: Used to describe the development of test specifications

Tracking work items and study items

The complete list of 3GPP work items back to Release 99 can be found at http://www.3gpp.org/ftp/Information/WORK_PLAN/

The list can be filtered by many attributes including the release, work item name and committee resource

Links are given to the latest work item descriptions and status reports

RAN, SA and CT plenary documents for meeting XX are at:
ftp://ftp.3gpp.org/tsg_ran/TSG_RAN/TSGR_XX/Docs/
ftp://ftp.3gpp.org/tsg_sa/TSG_SA/TSGS_XX/Docs/
ftp://ftp.3gpp.org/tsg_ct/TSG_CT/TSGC_XX/Docs/

Link work items to the affected specifications

If you know a work item code you can find out all the specifications that changed as a result of that work item

Go to:

http://www.3gpp.org/ftp/Specs/html-info/FeatureListFrameSet.htm

Select a release from the tabs at the top

Click on a feature or study item on the left hand side

Click on a unique ID (UID) on the right to see a list of affected specifications

Frequency bands – Release Independent

An important aspect of frequency bands when it comes to the 3GPP releases is that they are "release independent"

This means that a band defined in a later release can be applied to an earlier release.

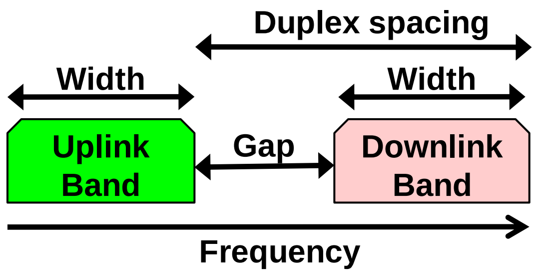
This significantly simplifies the specifications

	FDD	TDD
Release 8	1 – 17 (excl. 15,16*)	32 - 40
Release 9	18 - 21	
Release 10	22 - 25	41 - 43
Release 11	26 - 29	44
Release 12	30?, 31?, …	

* Bands 15 and 16 are specified by ETSI only for use in Europe

LTE FDD Frequency bands Sept 2012

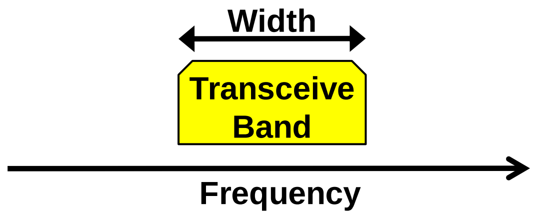
Band	Uplink MHz		Downlink MHz		Width	Duplex	Gap
1	1920	1980	2110	2170	60	190	130
2	1850	1910	1930	1990	60	80	20
3	1710	1785	1805	1880	75	95	20
4	1710	1755	2110	2155	45	400	355
5	824	849	869	894	25	45	20
6	830	840	865	875-	10	35	25
7	2500	2570	2620	2690	70	120	50
8	880	915	925	960	35	45	10
9	1749.9	1784.9	1844.9	1879.9	35	95	60
10	1710	1770	2110	2170	60	400	340
11	1427.9	1447.9	1475.9	1495.9	20	48	28
12	698	716	728	746	18	30	12
13	777	787	746	756	10	-31	21
14	788	798	758	768	10	-30	20
15*	1900	1920	2600	2620	20	700	680
16*	2010	2025	2585	2600	15	575	560
17	704	716	734	746	12	30	18
18	815	830	860	875	15	45	30
19	830	845	875	890	15	45	30
20	832	862	791	821	30	-41	11
21	1447.9	1462.9	1495.9	1510.9	15	48	33
22	3410	3490	3510	3590	80	100	20
23	2000	2020	2180	2200	20	180	160
24	1626.5	1660.5	1525	1559	34	-101.5	67.5
25	1850	1915	1930	1995	65	80	15
26	814	849	859	894	35	45	10
27	807	824	852	869	17	45	28
28	703	748	758	803	45	55	10



- There is a lot of overlap between band definitions for regional reasons
- The Duplex spacing varies from 30 MHz to 799 MHz
- The gap between downlink and uplink varies from 10 MHz to 680 MHz
- Narrow duplex spacing and gaps make it hard to design filters to prevent the transmitter spectral regrowth leaking into the receiver (self-blocking)
- Bands 13, 14, 20 and 24 have reversed uplink downlink frequencies
- Bands 15 and 16 are specified by ETSI only for use in Europe

LTE TDD Frequency bands Sept 2012

Band	Uplink MHz		Downlink MHz		Width
33	1900	1920	1900	1920	20
34	2010	2025	2010	2025	15
35	1850	1910	1850	1910	60
36	1930	1990	1930	1990	60
37	1910	1930	1910	1930	20
38	2570	2620	2570	2620	50
39	1880	1920	1880	1920	40
40	2300	2400	2300	2400	100
41	2496	2690	2496	2690	194
42	3400	3600	3400	3600	200
43	3600	3800	3600	3800	200
44	703	803	703	803	100



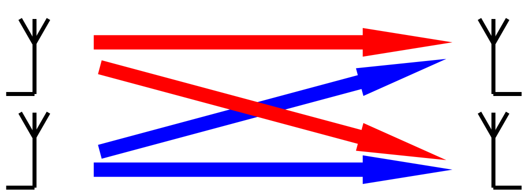
LTE Release 8

Nov 2004 LTE/SAE High level requirements

- Reduced cost per bit
- More lower cost services with better user experience
- Flexible use of new and existing frequency bands
- Simplified lower cost network with open interfaces
- Reduced terminal complexity and reasonable power consumption

DL SU-MIMO

MU-MIMO



X2 & X4 Multiple Input Multiple Output

Spectral Efficiency

3-4x Rel-6 HSDPA (downlink)

2-3x HSUPA (uplink)

Latency

Idle ➔ active < 100 ms

Small packets < 5 ms

SPEED!

Downlink peak data rates (64QAM)			
Antenna config	SISO	2x2 MIMO	4x4 MIMO
Peak data rate Mbps	100	172.8	326.4
Uplink peak data rates (Single antenna)			
Modulation	QPSK	16 QAM	64 QAM
Peak data rate Mbps	50	57.6	86.4

Flexible Channel Bandwidths

MHz
1.4
3
5
10
15
20

Mobility

Optimized: 0–15 km/h
High performance: 15-120 km/h
Functional: 120–350 km/h
Under consideration: 350–500 km/h

Release 9: Summary of key radio features (Dec 2009)

Home base station (femtocell)

MBMS – completion of MBSFN

Positioning Support (AGNSS)

Multicarrier / Multi-RAT Base Station (Multi Standard Radio)

Local Area Base Station (picocell)

Dual layer beamforming (TM8)

Self Organizing Networks (SON)

Release 10: Stage 3 frozen March 2011 Summary of key radio features

Carrier Aggregation (CA) – www.agilent.com/find/LTEwebcasts

Enhanced uplink transmission

- Clustered SC-FDMA
- Simultaneous PUCCH and PUSCH
- Transmit diversity, two- and four-layer spatial multiplexing

Enhanced downlink transmission

- Eight-layer spatial multiplexing including UE-specific RS (TM9)
- Channel State Information Reference Symbols (CSI-RS)

Relaying – continued in Release 11

Enhanced Inter-cell Interference Coordination (eICIC)

Minimization of Drive Test (MDT)

Machine Type Communications (MTC)

Inter-band (non contiguous) MSR - www.agilent.com/find/LTEwebcasts

SON enhancements for self healing

Release 11: Stage 3 frozen Sept 2012
Summary of key radio features

New carrier aggregation combinations (18)

Verification of radiated multi-antenna reception performance of UEs in LTE/UMTS (MIMO OTA)

Signaling and procedure for interference avoidance for in-device coexistence

Coordinated multi-point operation for LTE

Public Safety Broadband High Power UE for Band 14, Region 2

Rel-11 Carrier Aggregation combinations

Band	Lead company	Uplink	Downlink	Uplink	Downlink	Mode
CA-B3_B7*	TeliaSonera	1710 - 1785	1805 - 1880	2500 - 2570	2620 - 2690	FDD
CA-B4_B17	AT&T	1710 – 1755	2110 - 2155	704 – 716	734 - 746	FDD
CA-B4_B13	Ericsson (Verizon)	1710 – 1755	2110 - 2155	777 - 787	746 - 756	FDD
CA-B4_B12	Cox Communications	1710 – 1755	2110 - 2155	698 – 716	728 - 746	FDD
CA-B20_B7	Huawei (Orange)	832 – 862	791 - 821	2500 - 2570	2620 - 2690	FDD
CA-B2_B17	AT&T	1850 – 1910	1930 - 1990	704 – 716	734 - 746	FDD
CA-B4_B5	AT&T	1710 – 1755	2110 - 2155	824 – 849	869 - 894	FDD
CA-B5_B12	US Cellular	824 – 849	869 - 894	698 – 716	728 - 746	FDD
CA-B5_B17	AT&T	824 – 849	869 - 894	704 – 716	734 - 746	FDD
CA-B20_B3	Vodafone	832 – 862	791 - 821	1710 - 1785	1805 - 1880	FDD
CA-B20_B8	Vodafone	832 – 862	791 - 821	880 – 915	925 - 960	FDD
CA-B3_B5	SK Telecom	1710 - 1785	1805 - 1880	824 – 849	869 - 894	FDD
CA-B7	China Unicom	2500 - 2570	2620 - 2690	2500 - 2570	2620 - 2690	FDD
CA-B1_B7	China Telecomm	1920 - 1980	2110 - 2170	2500 - 2570	2620 - 2690	FDD
CA-B4_B7	Rogers Wireless	1710 – 1755	2110 - 2155	2500 - 2570	2620 - 2690	FDD
CA-B25_25	Sprint	1850 - 1915	1930 - 1995	1850 - 1915	1930 - 1995	FDD
CA-B38	Huawei (CMCC)	2570 - 2620	2570 - 2620	2570 - 2620	2570 - 2620	TDD
CA-B41	Clearwire	3600 - 3800	3600 - 3800	3600 - 3800	3600 - 3800	TDD

* Carried forwards from Rel-10

Combinations of carrier aggregation and layers

There are multiple combinations of CA and layers that can meet the data rates for the new and existing UE categories

The following tables define the most cases for which performance requirements may be developed

Downlink

UE category	capability [#CCs/BW(MHz)]	DL layers [max #layers]
Category 6	1 / 20MHz	4
	2 / 10+10MHz	4
	2 / 20+20MHz	2
	2 / 10+20MHz	4 (10MHz) 2(20MHz)
Category 7	1 / 20MHz	4
	2 / 10+10MHz	4
	2 / 20+20MHz	2
	2 / 10+20MHz	4 (10MHz) 2(20MHz)
Category 8	[2 / 20+20MHz]	[8]

Uplink

UE category	capability [#CCs/BW(MHz)]	UL layers [max #layers]
Category 6	1 / 20MHz	1
	2 / 10+10MHz	1
	1 / 10MHz	2
Category 7	2 / 20+20MHz	1
	1 / 20MHz	2
	2 / 10+20MHz	2 (10MHz) 1 (20MHz)
Category 8	[2 / 20+20MHz]	[4]

MIMO OTA: Verification of radiated multi-antenna reception performance of UEs

Unlike SISO OTA performance which was entirely a function of the DUT, MIMO OTA performance is intricately linked to the channel and operating conditions

Expected performance is impacted among other things by:

- Choice of channel model
- Doppler speed
- Degree of spatial diversity
- Impact of adaptive modulation and coding
- Noise and interference conditions
- Transmission mode used and transitions between modes

MIMO OTA test methodologies

Seven test methods have been proposed for the study item

They can be grouped into three main methods:

Multi-antenna anechoic chamber methods

- Configurations vary from simple two antenna with no fading up to as many as a ring of 32 antennas with fading

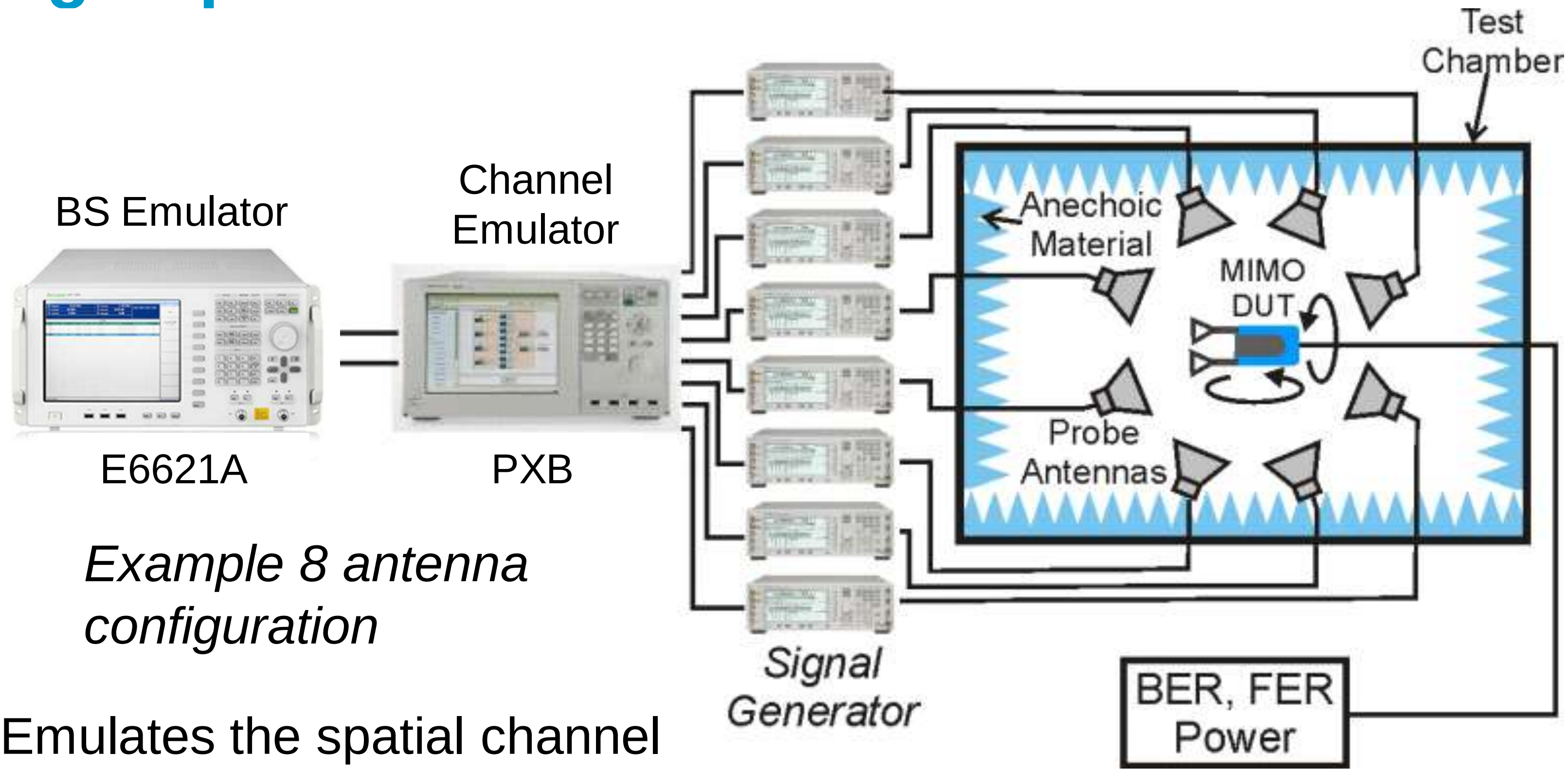
Reverberation chamber methods

- These vary from simple single chamber to more complex multi-chamber with or without the addition of a fading emulator

Antenna pattern method and two-stage method

- Antenna-only methods and the more advanced two-stage method involving throughput measurement

Ring of probes anechoic method



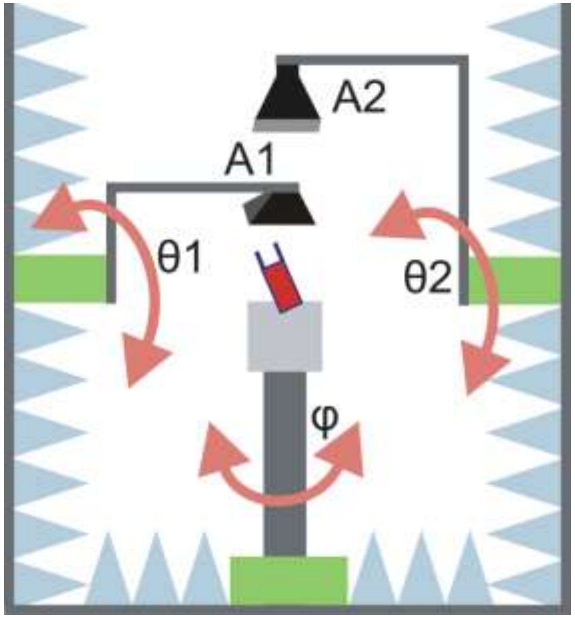
Example 8 antenna configuration

- Emulates the spatial channel
- Conceptually simple
- Requires new anechoic chamber design with probably 16 x 2 cross polarized probes – (a less flexible single cluster solution simplifies this)
- System calibration likely to be challenging to verify “quiet zone” performance
- Extending to 3D adds further cost and complexity

Two-channel anechoic method (Decomposition approach)

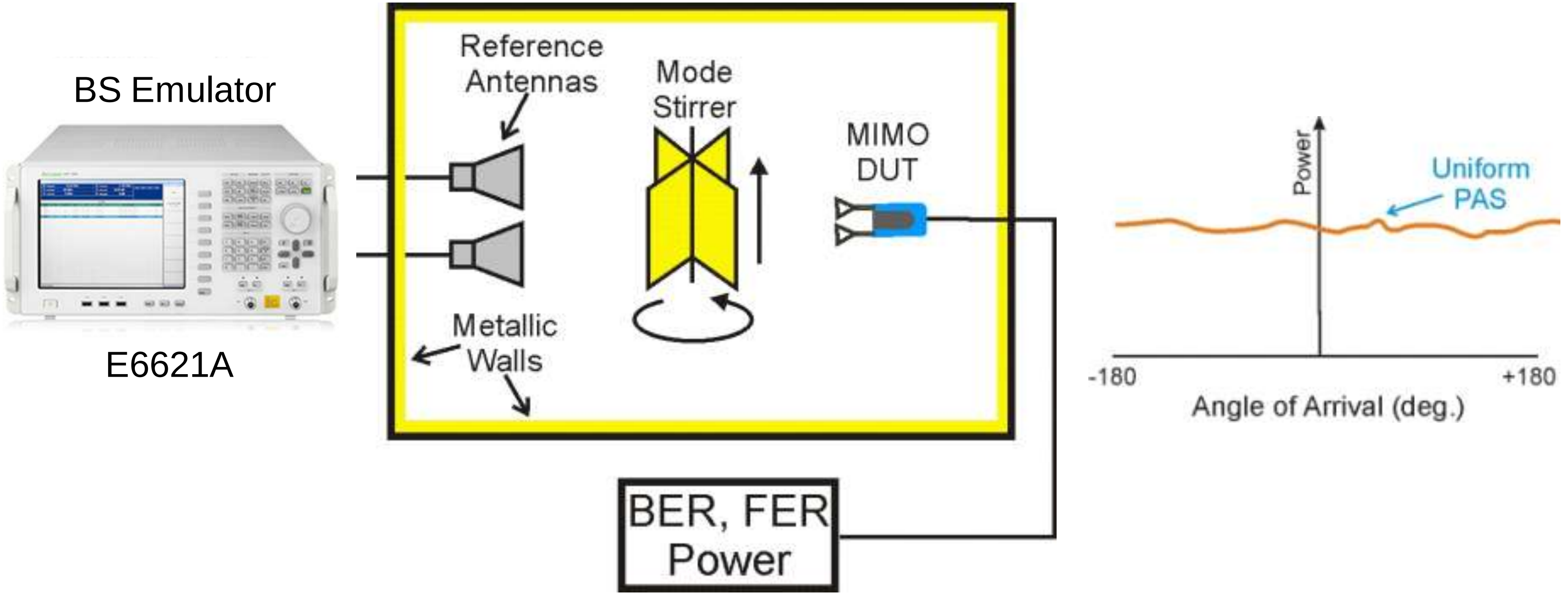
A test point is defined by:

- Signal from BS Emulator, e.g. frequency, MCS, data rate, MIMO mode, …
- Fading characteristics (if applicable) and antenna polarisations
- Antenna positions
- UE position elevation, azimuth



- Two independent line of sight signals rotate around the DUT at different angular separations
- The measurement then uses the quantities CQI, RI and PMI for a quick evaluation of the channel characteristics for each given test point
- Low cost –channel emulation not essential
- 3D capable
- Can't emulate standard channel models

Reverberation chamber methods

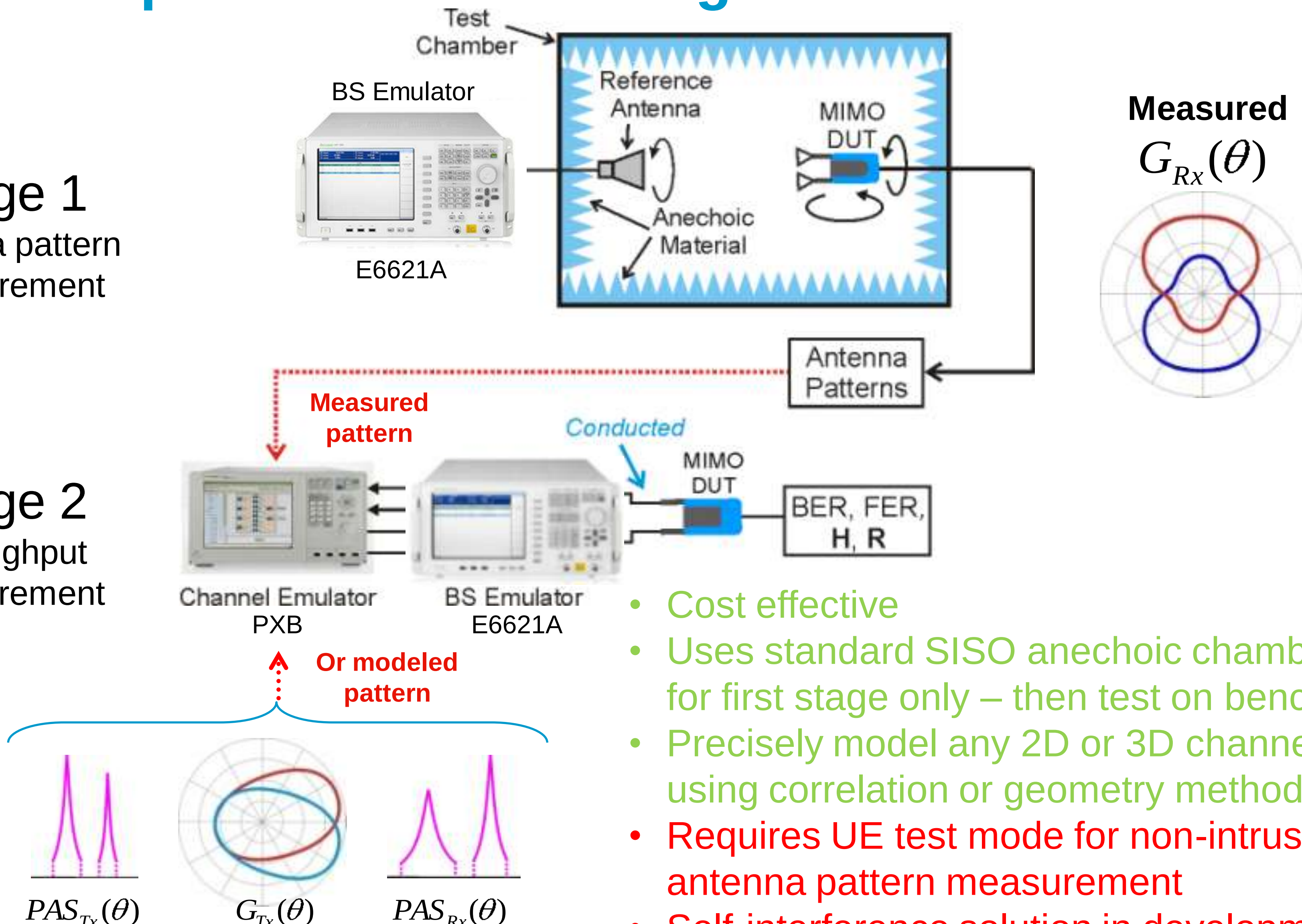


- The basic power delay profile (PDP) is modified using absorbers
- Adding a fading emulator can further modify the PDP
- Chambers can be cascaded or nested to create more complex signals
- Cost effective
- Good for assessing self-blocking
- No direct control over spatial aspects – angle of arrival is random

Antenna pattern and two-stage method

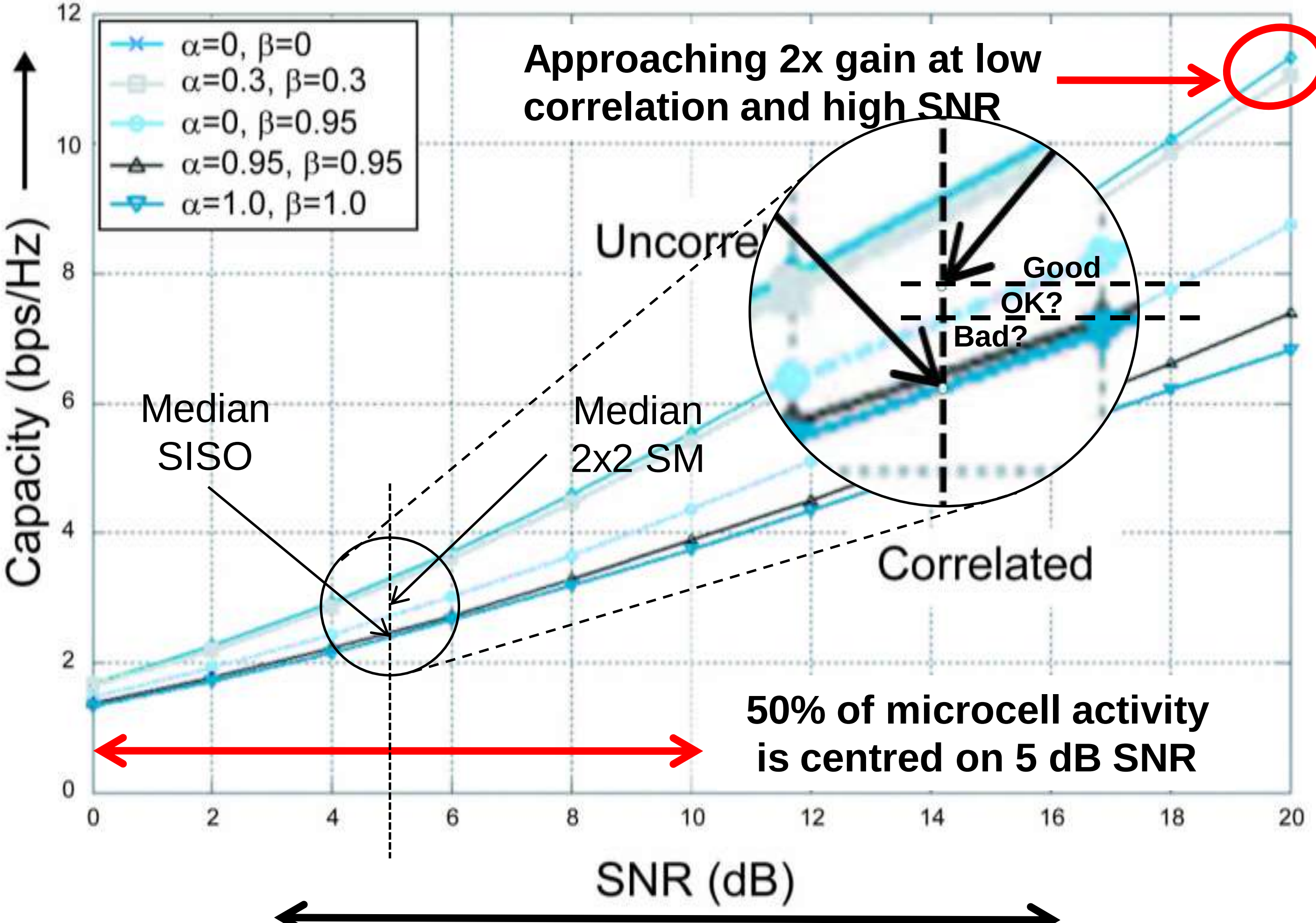
Stage 1
Antenna pattern measurement

Stage 2
Throughput measurement



- Cost effective
- Uses standard SISO anechoic chamber for first stage only – then test on bench
- Precisely model any 2D or 3D channel using correlation or geometry methods
- Requires UE test mode for non-intrusive antenna pattern measurement
- Self-interference solution in development

What should we expect from MIMO in median conditions?



Variation due to antenna correlation

(Additional variation in the channel and frequency domain not shown)

In median conditions the capacity gain of MIMO is very small making it difficult to distinguish between good and bad performance

Variation due to fading and statistical interference

Signaling and procedure for interference avoidance for in-device coexistence

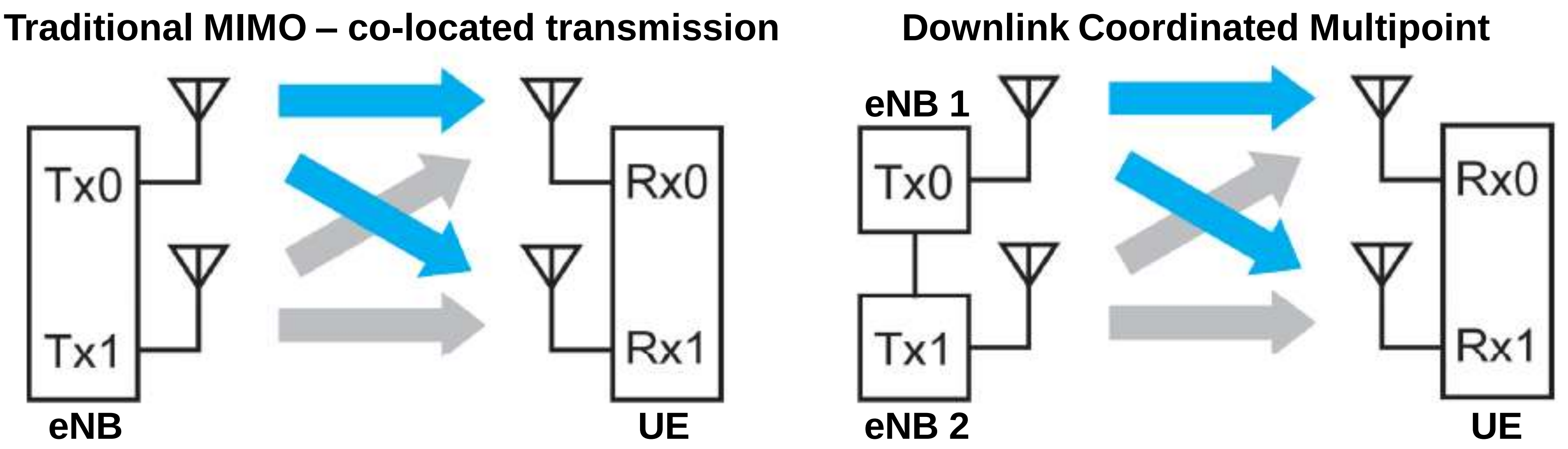
Due to the growing complexity of multiband and multi-format radios it is no longer possible to guarantee a UE transmitter will not block one of its own receivers

To help mitigate this potential a new in-device coexistence (IDC) indication message has been defined for the UE.

This message enables the UE to alert the network of an interference issue and provide information regarding the direction and nature of the interference, which may be identified in either the time or frequency domain.

Upon receipt of the IDC message the network will take appropriate steps to alleviate the problem by reallocating radio resources.

Coordinated Multi-Point – (CoMP)



By coordinating transmission and reception across geographically separated locations (points) it is possible to enhance network performance

This includes coordinated scheduling and beamforming as well as joint reception

Full performance requires baseband connection between points

CoMP Scenarios
TR 36.819

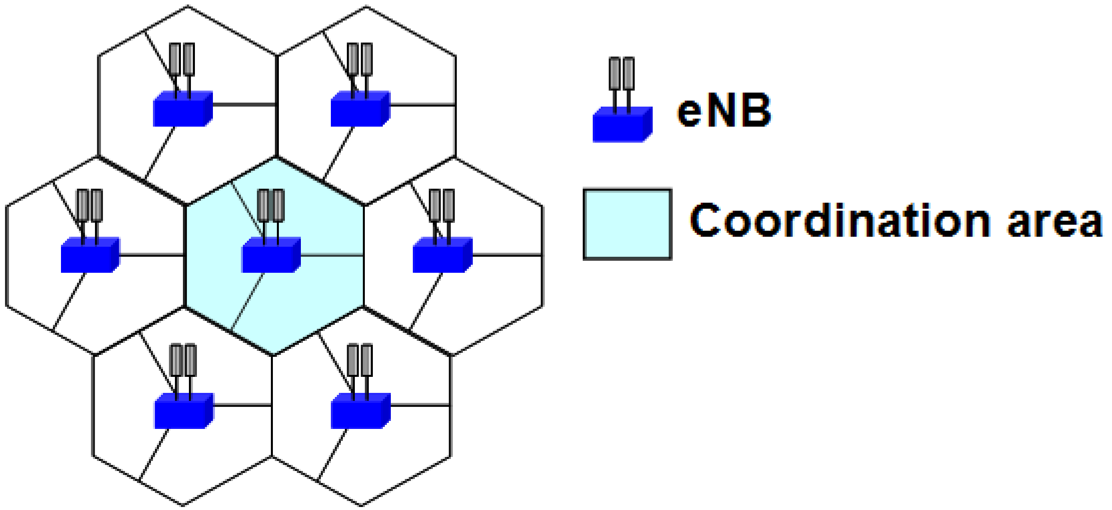


Figure A.1-1: Scenario 1 - Homogeneous network with intra-site CoMP

CoMP Scenarios
TR 36.819

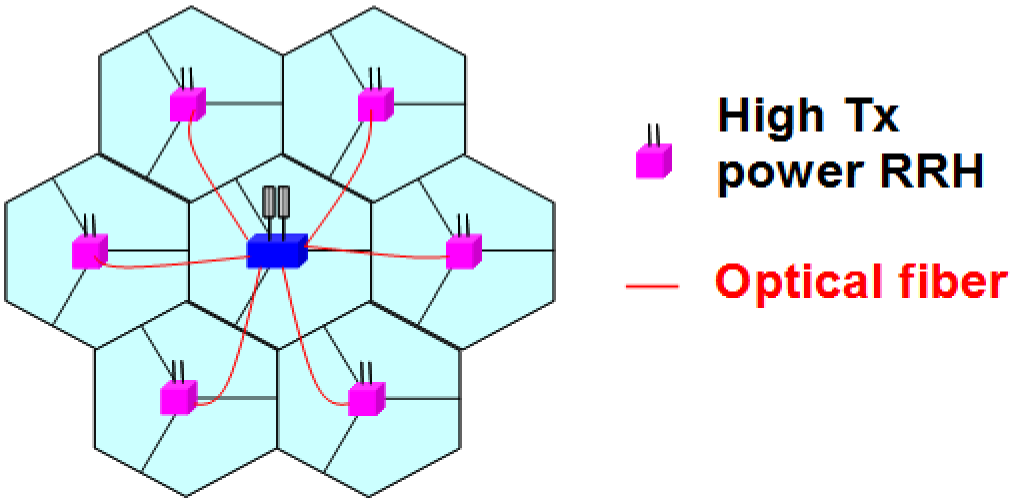


Figure A.1-2: Scenario 2 - Homogeneous network with high Tx power RRHs

CoMP Scenarios
TR 36.819

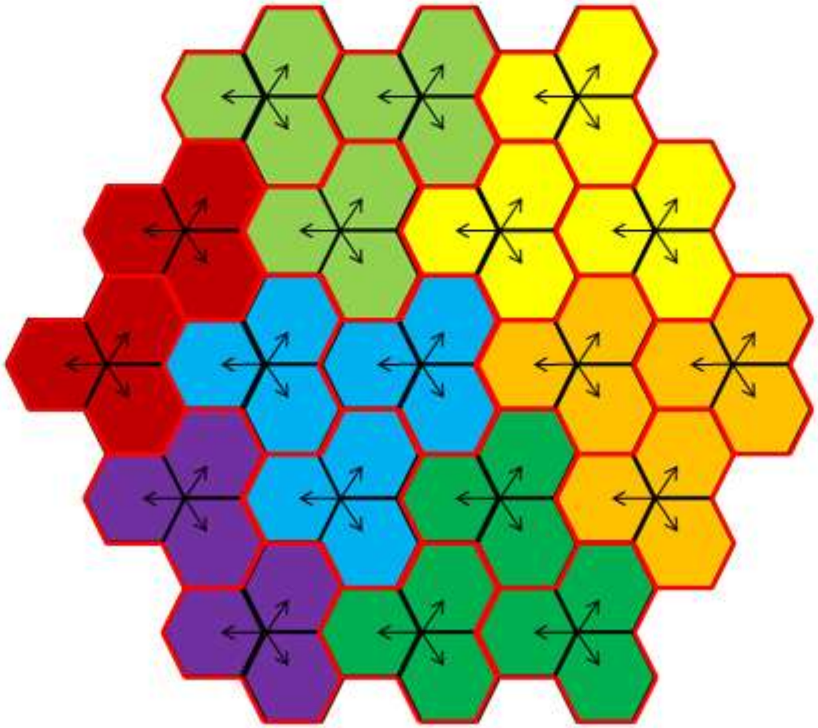


Figure A.1-3- Reference CoMP Coordination Cell Layout for Scenario 2

CoMP Scenarios
TR 36.819

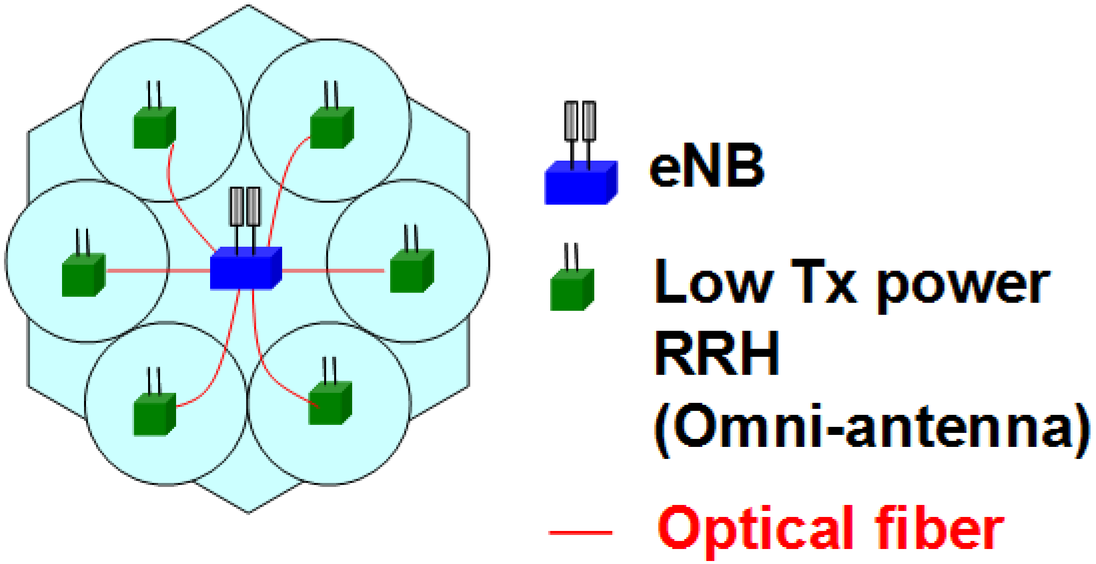


Figure A.1-4: Scenario 3/4 - Network with low power RRHs within the macrocell coverage

In scenario 3 the transmission/reception points created by the RRHs have different cell identifications than does the macro cell and for scenario 4 the cell identifications are the same as that of the macro cell.

CoMP Downlink Categories

Joint Processing (JP)

- Joint Transmission (JT)
  - This is a form of spatial multiplexing that takes advantage of decorrelated transmission from more than one point within the cooperating set. Data to a UE is simultaneously transmitted from multiple points; e.g., to coherently or non-coherently improve the received signal quality or data throughput.
- Dynamic Point Selection (DPS) / muting
  - The UE data is available at all points in the cooperating set but is only transmitted from one point based on dynamic selection in time and frequency. This data? includes dynamic cell selection (DCS).
- DPS may be combined with JT, in which case multiple points can be selected for data transmission in the time-frequency resource.

CoMP Downlink Categories

Coordinated scheduling and beamforming (CS/CB)

- Data for a UE is only available at and transmitted from one point in the CoMP cooperating set but user scheduling and beamforming decisions are made across all points in the cooperating set. Semi-static point selection (SSPS) is used to make the transmission decisions.

Dynamic or semi-static muting may be applied to both JP and CS/CB.

Hybrid JP and CS/CB

- Data for a UE may be available in a subset of points in the CoMP cooperating set for a time-frequency resource but user scheduling and beamforming decisions are made with coordination among points corresponding to the CoMP cooperating set. For example, some points in the cooperating set may transmit data to the target UE according to JP while other points in the cooperating set may perform CS/CB.

CoMP Uplink Categories

Joint reception (JR)

- The PUSCH transmitted by the UE is simultaneously (jointly) received at some or all of the points in the cooperating set. This simultaneous reception can be used with inter-point processing to improve the received signal quality

Coordinated scheduling and beamforming (CS/CB)

- User scheduling and precoding selection decisions are made with coordination among points corresponding to the cooperating set. Data is intended for one point only.

CoMP Performance

Extensive simulation ahs been carried out for the four scenarios under different operating conditions.

Results are mixed and vary from negligible gain or small loss of performance up to around 80% gain for specific TDD cases where the eNB can exploit channel reciprocity for channel estimation purposes. Typical gains are in the 10% - 30% range.

The release 11 work item will focus on:

- Joint transmission
- DPS, including dynamic point blanking
- CS/CB, including dynamic point blanking.

Specifying performance requirements will be very difficult due to the interaction between UE reporting and network algorithms

Public Safety Broadband High Power UE (HPUE) for Band 14, Region 2 (USA)

Most commercial networks target 95% population coverage but US public safety is targeting 99% - this last 4% requires a 60% larger coverage area

Solving this with a more dense network would be very expensive

The alternative is to specify a new 33 dBm power class UE

This can benefit from much higher performance vehicular mounted antennas

In general most RF requirements become 10 dB harder to meet

Existing SAW duplex filters will probably need to be replaced by much larger ceramic or cavity filters

Release 11: Stage 3 freeze Sept 2012
Other radio features

LTE RAN enhancements for diverse data applications

- Dealing with consequences of everything from IM to streaming video

Further Enhanced Inter-cell Interference Coordination (FeICIC)

Network energy saving for the E-UTRAN

Enhanced downlink control channel(s) for LTE-Advanced

Improved minimum performance requirements for E-UTRA: interference rejection

- Using more complex realistic interference models

Additional special subframe configuration for LTE TDD

- Optimizing use of special subframe for data transmission

3GPP Release 12 Workshop June 2012

In June 2012 3GPP RAN held a workshop on Release 12

Around 50 companies submitted their future vision

The submissions and report can be found at:

ftp://ftp.3gpp.org/workshop/2012-06-11_12_RAN_REL12

The broad areas for future evolution were identified as:

- Energy saving
- Cost efficiency
- Support for diverse application and traffic types
- Backhaul enhancements

3GPP Release 12 Workshop June 2012

The following proposals from the workshop were identified as most likely to be developed in Release 12:

- Interference coordination and management
- Dynamic TDD
- Enhanced discovery and mobility
- Frequency separation between macro and small cells, using higher frequency bands in small cells (e.g., 3.5 GHz)
- Inter-site carrier aggregation and macrocell-assisted small cells
- Wireless backhaul for small cells.

3GPP Release 12 Workshop June 2012

Other possible areas for study included:

- Support for diverse traffic types (control signaling reduction, etc.)
- Interworking with Wi-Fi
- Continuous enhancements for machine-type communications, SON, MDT, and advanced receivers
- Proximity services and device-to-device communications
- Further enhancements for HSPA including interworking with LTE.

Release 12: Stage 1 March 2013, stage 3 2014? Current Work Items

The Release 12 work items that have been defined so far are:

- New frequency bands
- 13 new carrier aggregation scenarios
  – Bringing the total to 31 for Rel-11 & 12 to date
- Carrier-based Het-Net ICIC for LTE
  – Extends existing co-channel ICIC to include network-based carrier selection
- New Carrier Type for LTE
  – The so-called “lean” carrier – not backwards compatible with Rel-8. Less control channel overhead, can be switched on and off based on load
- Further Downlink MIMO Enhancement for LTE-Advanced
- Further enhancements for H(e)NB mobility (part 3)
  – Inter H(eNB) and H(e)NB to macro

Release 12:
New Frequency Bands

Three new FDD frequency bands will be defined:

- Downlink 1670 MHz–1675 MHz, uplink 1646.7 MHz–1651.7 MHz
  - for ITU Region 2 (US)
- Downlink 461MHz–468 MHz, uplink 451–458 MHz
  - for Brazil
- Downlink 2350–2360 MHz, uplink 2305–2315 MHz
  - US Wireless Communications Service (WCS) band

There is also a study item for:

- Uplink 1980–2010 MHz and downlink 2170 MHz– 2200 MHz.
  - This is currently widely allocated for satellite communications but terrestrial use now being considered, particularly for ITU Region 3.
  - The potential for 110 MHz pairing with band 1 is also being considered.

Release 12: New Intra-band CA scenarios

Five new intra-band scenarios will be defined:

- Band 1 (contiguous)
- Band 3 (non-contiguous), carried over from Release 11
- Band 3 (contiguous)
- Band 4 (non-contiguous)
- Band 25 (non-contiguous).

Release 12: New Inter-band CA scenarios

An additional eight inter-band scenarios will be defined

- Bands 3 and 5 with two uplink carriers
- Bands 2 and 4
- Bands 3 and 26
- Bands 3 and 28
- Bands 3 and 19
- Bands 38 and 39
- Bands 23 and 29*
- Bands 1 and 8.

Band 29 is being specified as part of Release11. It is a downlink-only band from 717 to 728 MHz and to be used only for the purposes of carrier aggregation with other bands.

Further Downlink MIMO Enhancement for LTE-Advanced

The scope of the work item will cover the following topics:

- Four transmit antenna PMI feedback codebook enhancements to provide finer spatial domain granularity and to support different antenna configurations for macro and small cells, especially cross-polarized antennas, both closely and widely spaced, and non-co-located antennas with power imbalance
- New CSI feedback mode providing subband CQI and subband PMI
- Finer frequency-domain granularity
- Enhanced control of the reported rank and corresponding assumptions for CQI/PMI derivation to improve support for MU-MIMO.

Release 12: Current Study Items

Passive Intermodulation Handling for UTRA and LTE Base Stations

- Consequence of high power multicarrier transmission

Mobile Relaying

- High speed train scenario – relay on board with group handover

Positioning based on RF pattern matching

RF and EMC Requirements for Active Antenna Array System (AAS)

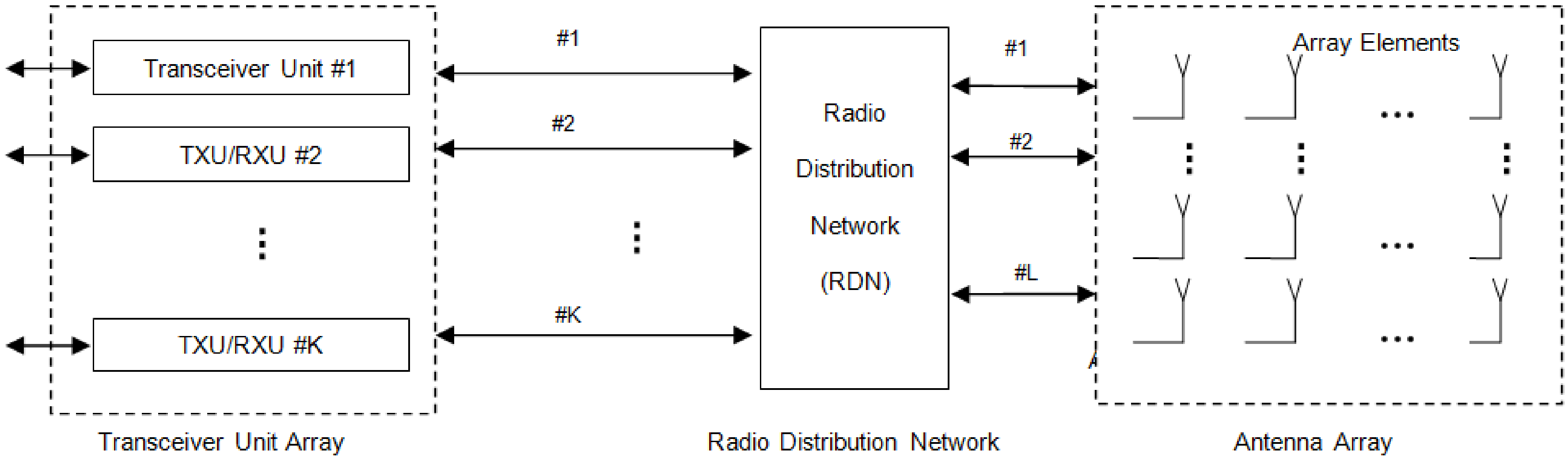
Scenarios and Requirements of LTE Small Cell Enhancements

LTE-Direct

Active Antenna Systems (AAS)

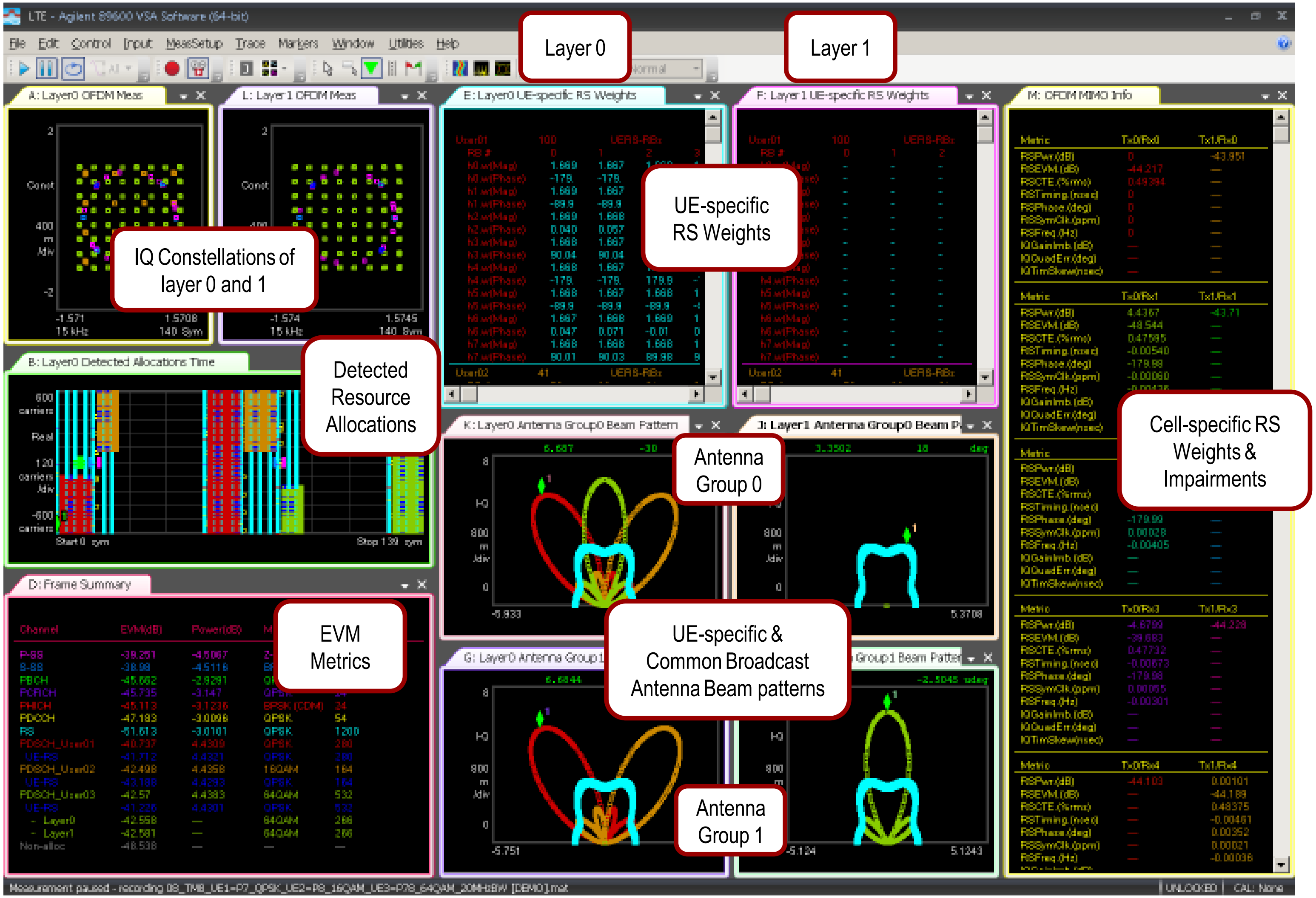
The exploitation of multiple antennas in base stations has been ongoing for years but has never been standardized

- This is changing since radio link assumptions of simple three-sectored cells no longer represents network reality
- The challenge is how to specify eNB performance in the spatial domain

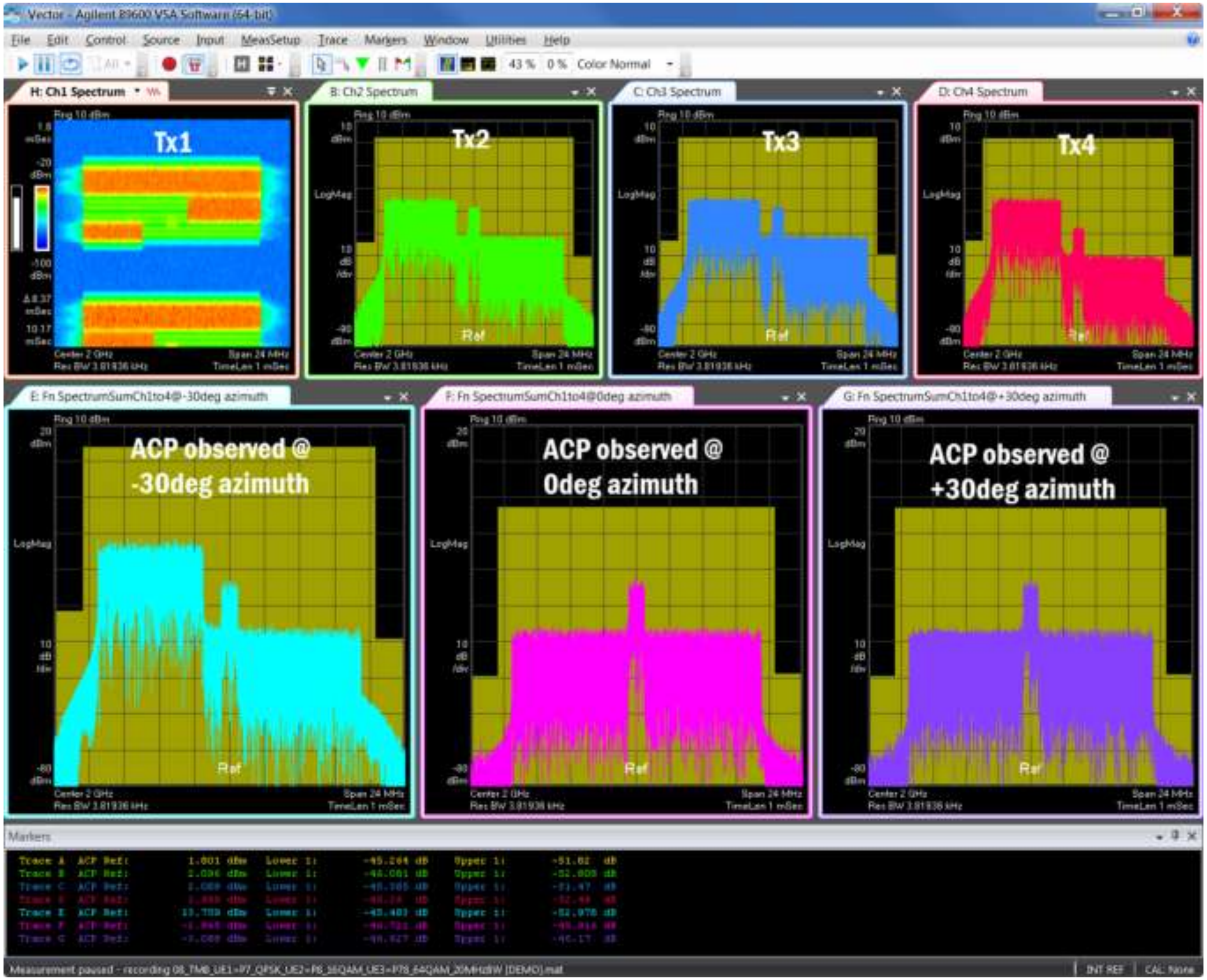


General AAS Radio Architecture (TR 37.840 Figure 4.2-1)

AAS: Visualization of 8 antenna beamforming using multi-channel phase coherent analysis



Spatial ACLR measurements for 4 Tx eNB



A: Spectrogram for TX1

B: ACLR for TX2

C: ACLR for TX3

D: ACLR for TX4

E: ACLR @ -30°

F: ACLR @ 0°

G: ACLR @ 30°

Noise at channel centre is due to omnidirectional control channels

Scenarios and Requirements of LTE Small Cell Enhancements

For a considerable time the focus of RAN standardization activities has been on wider bandwidths and higher spectral efficiency

Both lead to higher system performance

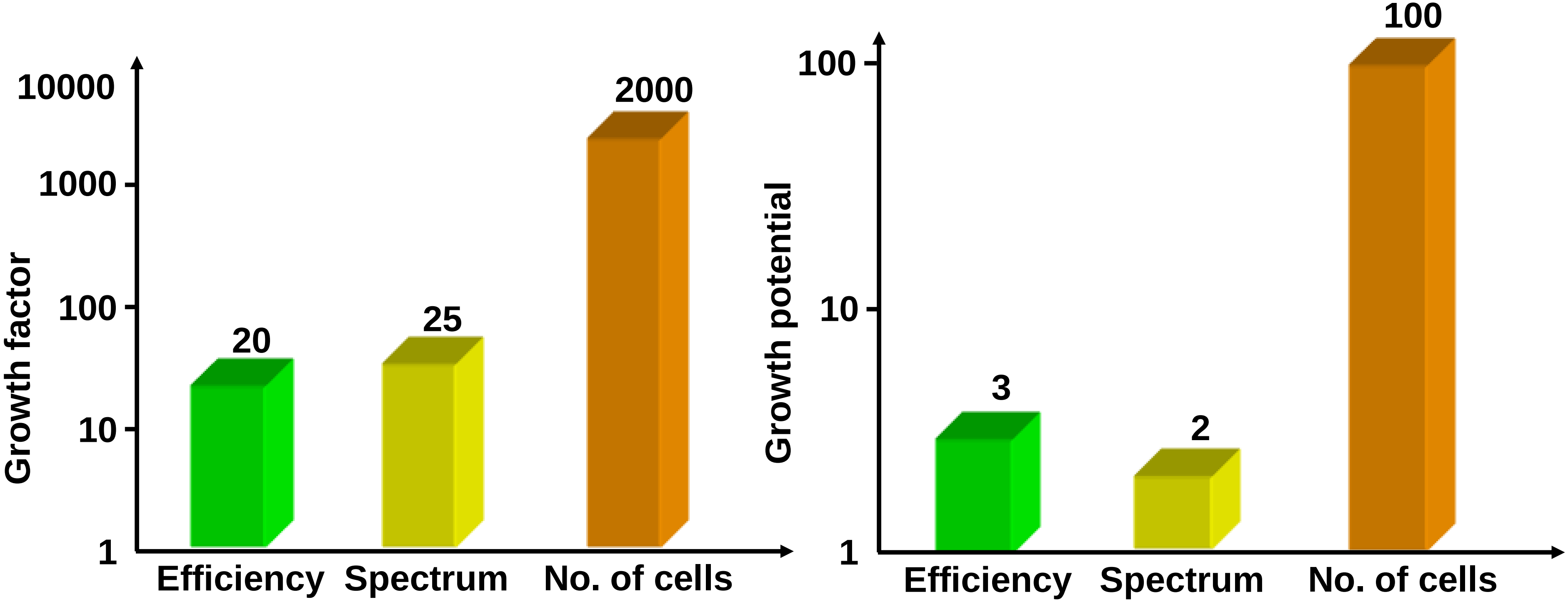
However, the potential for the third dimension of frequency reuse as a means of improving system performance

- Many RAN features already exist to facilitate spectral reuse such as femtocells and Heterogeneous networks but the propagation, mobility, interference, and backhaul needs of small cells are very different to the assumptions that were used to define the original heterogeneous model
- This study item will take a strategic look at how the RAN may be improved to maximize the benefits of small cells

Wireless capacity growth

1960 – 2010
Capacity 1,000,000x

2010 – 2020
Capacity 600x



For both the past and the future, the growth of wireless capacity is dominated by the number of cells (small cell spectrum reuse)

LTE-Direct

The final Release 12 study item of interest represent a fundamentally new concept in device communications

The scope is in two main phases:

- Device to device discovery
- Device to device (D2D) communication

The application for the first phase is to enable devices to “express” their identity to other UE in the local area

- This can be used for a variety of purposes including location based advertising

The second phase of D2D has all kinds of uses including public safety involving communication in the absence of a network

LTE-Direct

Device discovery can be enabled by the eNB scheduling periods in the uplink when different UE can broadcast their identity

- The mechanics of this are not complex but the interference potential to the network including new device to device co-existence issues needs to be thoroughly studied
- The UE would need to be enabled with an uplink receiver which creates in-device co-existence issues with the UE transmitter
- Security and privacy aspects are also of significance

For D2D in the absence of a network there would need to be a complete rethink about synchronization

- This is not likely to be tackled within the Release 12 timeframe

Agilent LTE Design and Test Portfolio

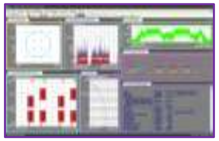
SystemVue (BB)
ADS/GG (RF/A)

Signal creation software

Signal Generators

Baseband Generator and Channel Emulator

RDX for DigRF v4



89600 VSA/WLA
For Signal Analyzers, Scopes, LA , SystemVue and ADS

Scopes and Logic Analyzers

Signal Analyzers with LTE Measurement Apps

Battery drain characterization

Design Simulation →

RF Module Development
- **RF Proto** → **RF Chip/module**

BTS and Mobile BB Chipset Development
L1/PHY
- **FPGA and ASIC**

Protocol Development
L2/L3

→ **RF and BB Design Integration**
L1/PHY
- **DigRF v4**
- **BTS or Mobile**

→ **System Design Validation**
System Level RF Testing

→ **Pre-Conformance** ↓ **Conformance** ↓ **Manufacturing** ↓ **Network Deployment**

RF & Protocol test platforms

LTE signalling conformance test

N5972A IFT Software

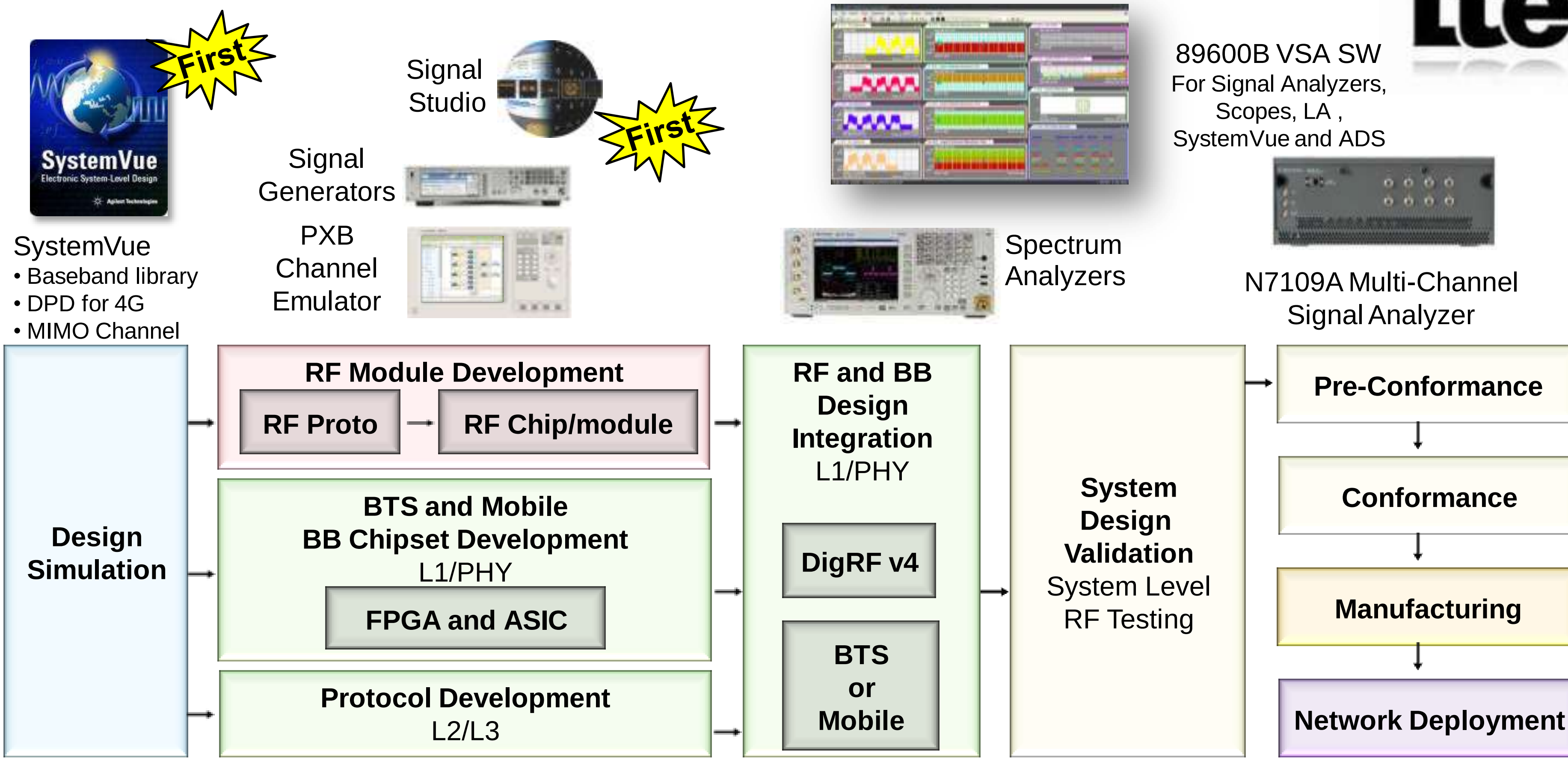
Systems for RF and Protocol Conformance

Manufacturing test platforms

N7109A Multi-Channel Signal Analyzer

RF Handheld Analyzers

First to Market Solutions for LTE-Advanced



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Summary

The evolution of LTE since Release 8 continues apace

Many of the most important innovations are recognizing the importance of network aspects towards improving end user performance rather than the traditional focus on spectral efficiency and peak channel bandwidth

- Heterogeneous networks
- Frequency reuse
- Mobility – heterogeneous carrier aggregation
- Inter-RAT aggregation including Wi-Fi

Questions