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Infocom World Conference - Athens

Key technologies behind the drive for 6G networks

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Beyond 5G: Introduction.

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3GPP has started work on '5G-Advanced' from Release 18, and industry/academia is already evaluating technologies for 6G.

Anritsu is participating in multiple projects and consortiums to help define and shape the future telecoms technologies, and the related measurement requirements.

Key technologies such as sub-THz frequency devices and bands, full duplex transmission, AI/ML in the air interface, dis-aggregated and virtualised networks, all-photonic networks, and (green) energy efficiency are all central themes for networks beyond 5G that are expected to create new measurement requirements.

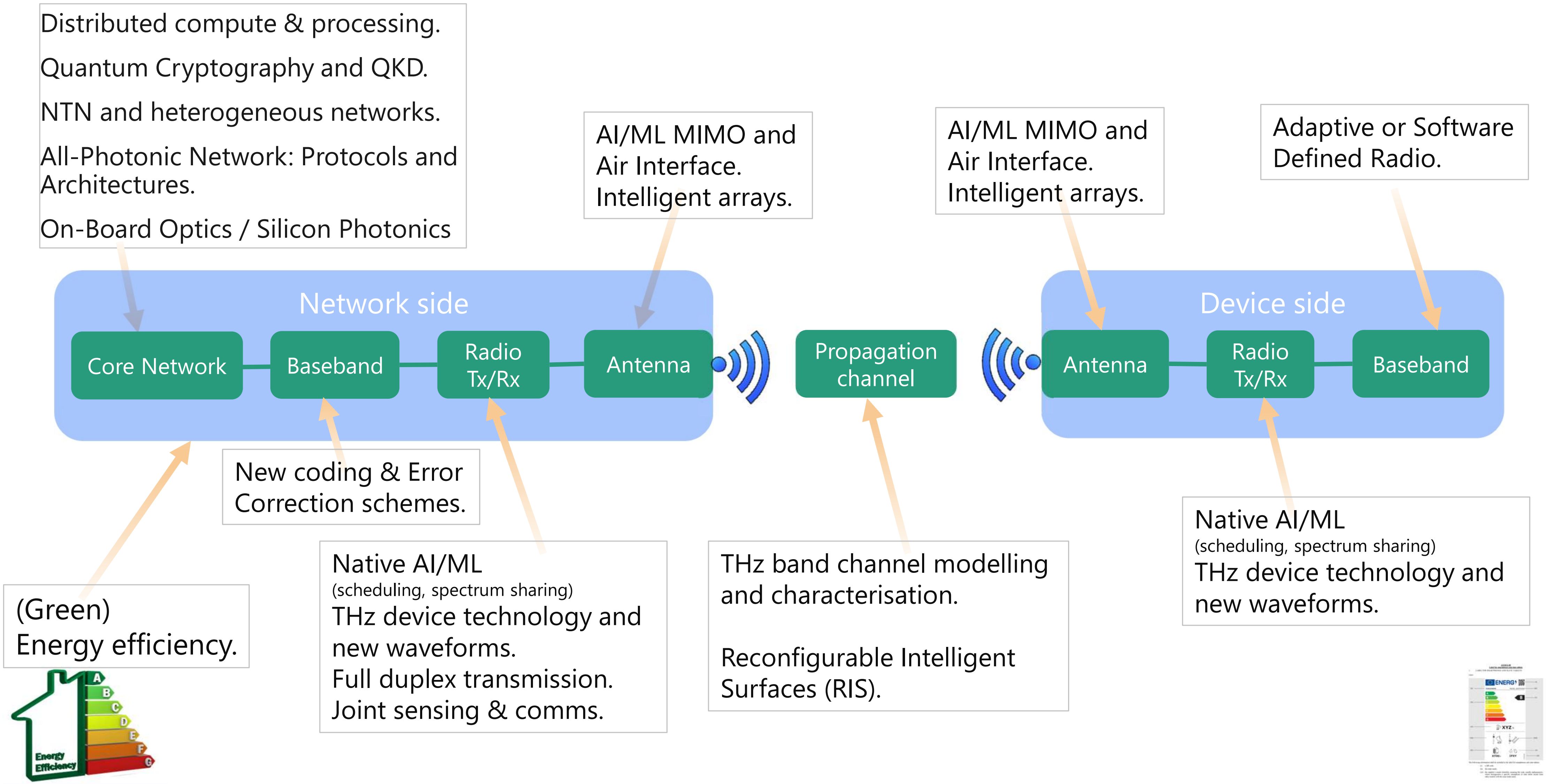
NEXT G ALLIANCE

NGMN

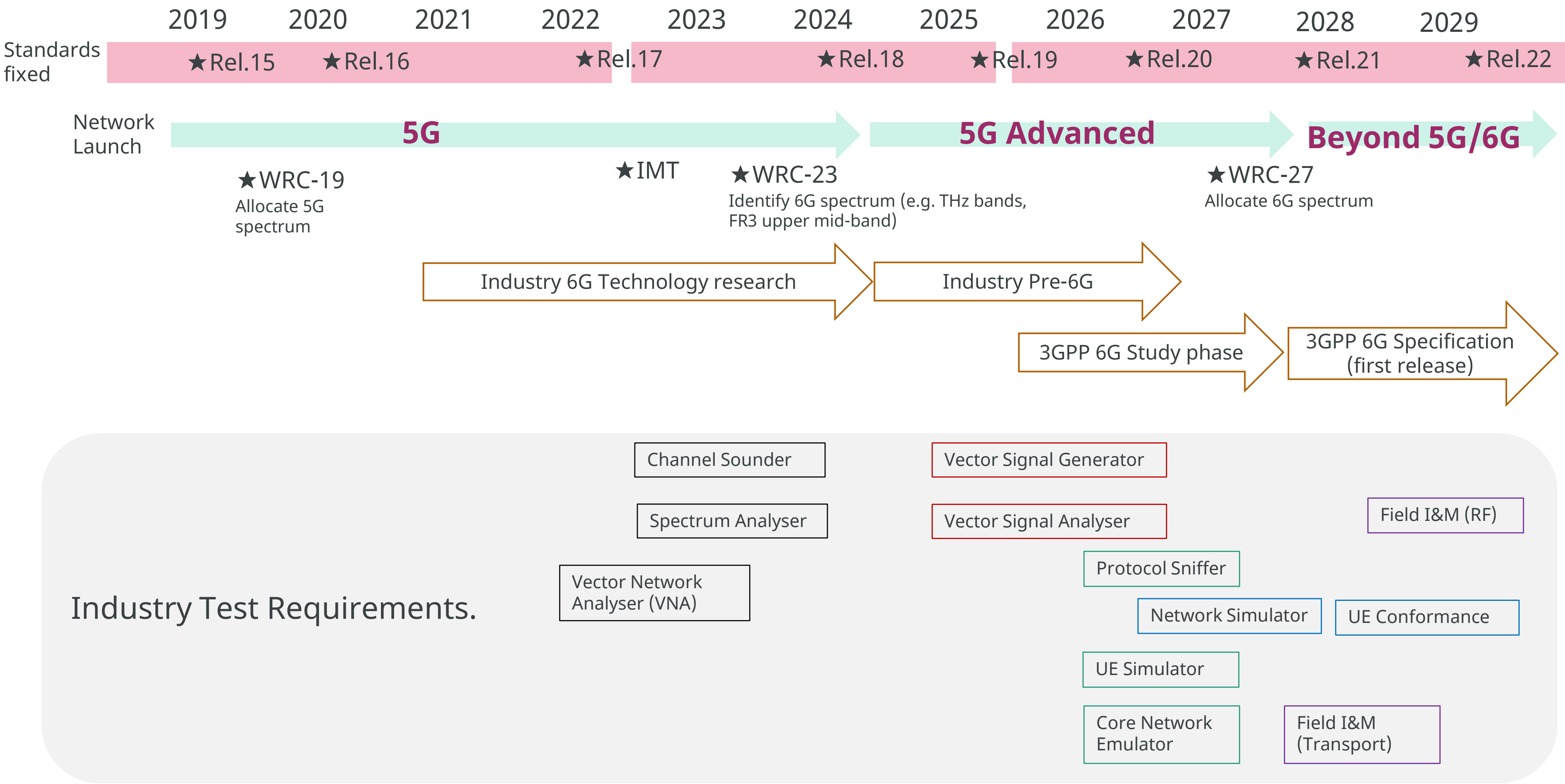
IOWN GLOBAL FORUM

ETSI MEMBER

Beyond 5G: Research topics in industry.



3GPP Technology roadmap



Anritsu 6G activities

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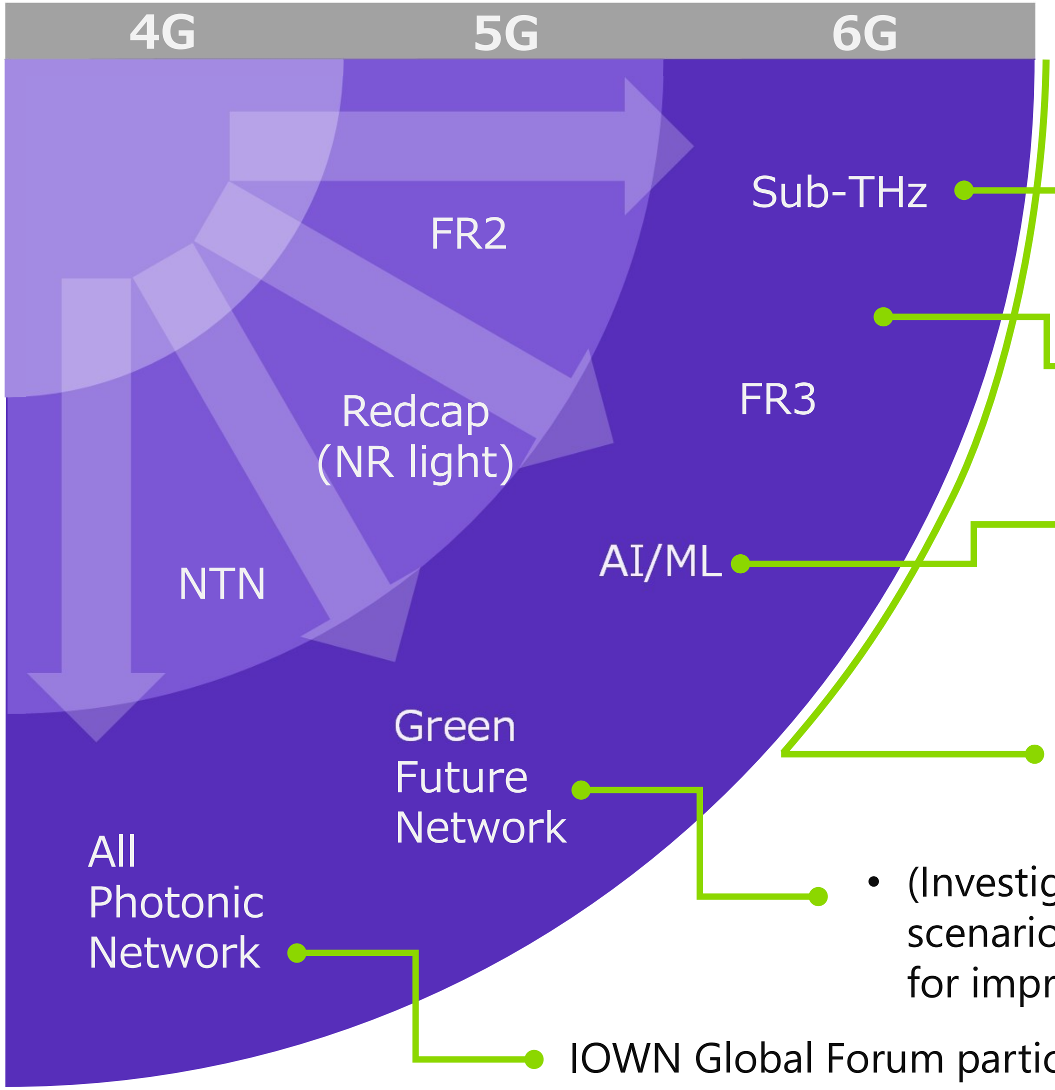


- 300GHz Spectrum Analyser
- 300GHz Wideband phase measurements
- High performance VNA measurement system

- (Study) Novel Channel Sounding techniques including RIS and ISAC.

- (Concept only) AI model Life Cycle Management (training, deployment, and operation)

- Solution for new test demands in B5G/6G era
  FST : Field Simulation Tester
  VST : Virtual Signaling Tester

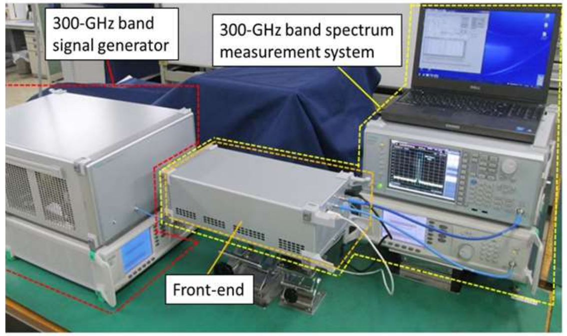
- (Investigation only) Network monitoring and network emulation scenarios to show enhancements and concepts for improving energy efficiency.

IOWN Global Forum participation

Sub-THz technology

300-GHz band spectrum measurement system

External appearance of measurement system



300 GHz Spectrum Analyser

This is a research project to develop the 'Proof of Concept' of a future spectrum analyser optimised for terahertz band measurements.

Conventional solutions use a down converter to bring a terahertz signal down to the normal operating range of the spectrum analyser, but this down conversion process does not have any pre-selector filter to prevent the unwanted image response frequencies being combined into the required signal band.

So we developed a novel pre-selector filter technology to enable spectrum analysis in the terahertz band without the problem of image response.

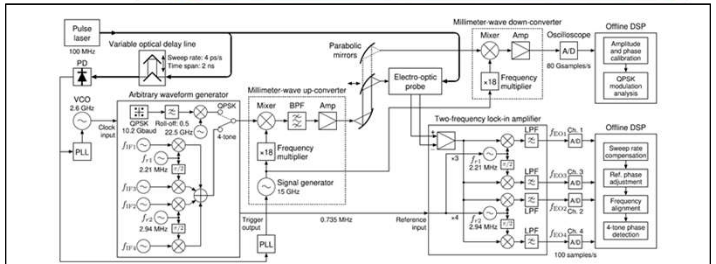
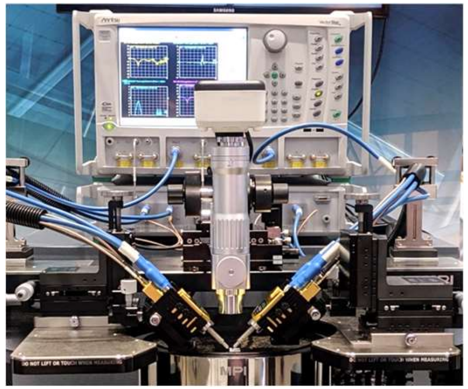


Fig. 2. Experimental setup for phase calibration of millimeter-wave up-converter using electro-optic sampling. A/D: analog-to-digital converter, BPF: bandpass filter, DSP: digital signal processing, LPF: low-pass filter, PD: photodiode, PLL: phase lock loop, QPSK: quadrature phase shift keying, VCO: voltage controlled oscillator.

300 GHz Phase compensation measurements.

A wide bandwidth (> 10GHz) stable phase sampling system is required for making phase calibration measurements.

Phase calibration measurements are used to create phase compensation terms to reduce non-linearity.



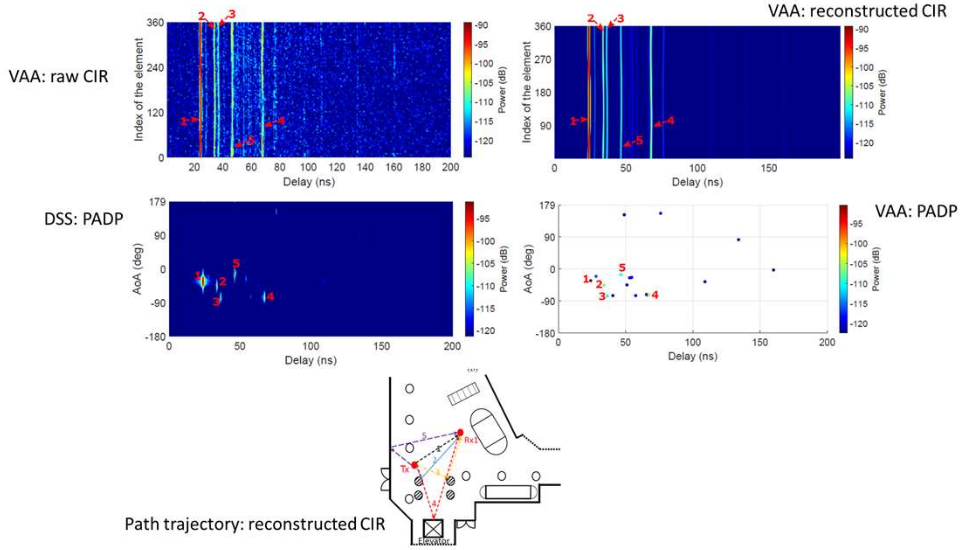
220 GHz broadband Vector Network Analyser (with SpA option).

Designing highly integrated on-wafer systems require circuit simulations using accurate device models generated through vector network analysis across an extremely wide continuous bandwidth.

The Anritsu VectorStar ME7838G and ME7838G4 broadband systems offer the industry's widest frequency coverage spanning 70 kHz to 220 GHz in a single sweep. It is available in 2 and 4-port versions for single-ended and differential circuit analysis.

Novel Channel Sounding techniques 1/3

- Joint collab. with Aalborg University(Denmark).
- VNA-based channel sounder that recovers accurate path phase information.
- Virtual Antenna Array (VAA) improves sensitivity and accuracy of path evaluation.
- Presented in Next-G alliance



VNA : ME7868A

- Suitable for highly isolated (>100m) measurements of multipath characteristics in high-density environments (e.g. factories/warehouses) where MIMO path diversity is available.
- Supports simultaneous FR1, FR2, and FR3 measurements in a single sweep up to 43 GHz.

VNA ME7868A

Novel Channel Sounding techniques 2/3

Example of measured channel impulse response(CIR) :

Outdoor LOS (Tx-Rx = 78m)

Outdoor NLOS (Tx-Rx = 70m)

3.5GHz

11GHz

29GHz

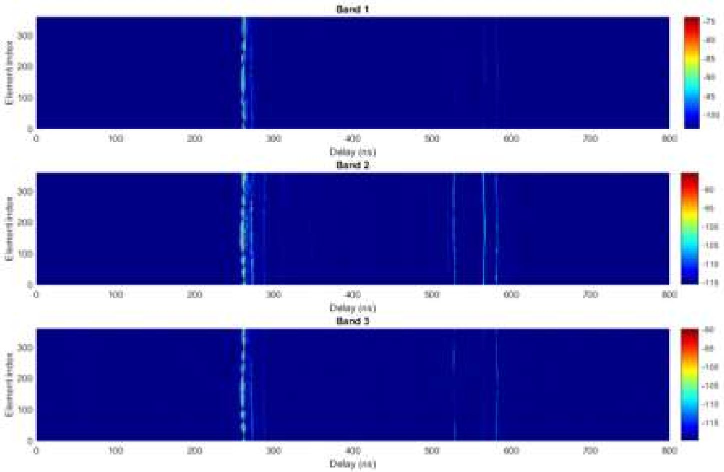


Fig. 2.35 CIRs results in 3 bands for the LOS case.

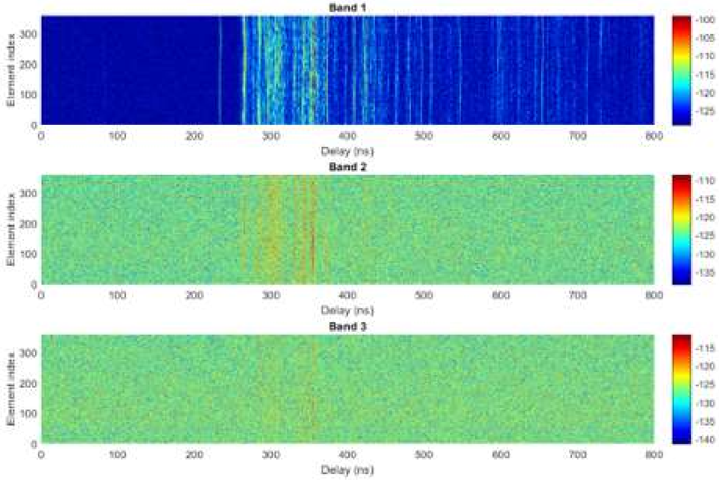


Fig. 2.36 CIRs results in 3 bands for the non-LOS case.

Novel Channel Sounding techniques 3/3

Verified:

1. FR3 (8-12 GHz) directive VAA methodology by distributed VNA
2. Comparison with results measured by conventional VNA

Ongoing(As of Oct. 2023) :

3. Develop a channel prediction/tracking algorithm based on the vast amount of measured channel response.

Stage 2 : Joint Comms And Sensing (JCAS) VNA channel sounder concept.
FR1/FR2/FR3 + D-band (especially 140-170GHz).

Room sensing measurement scenario (entrance).

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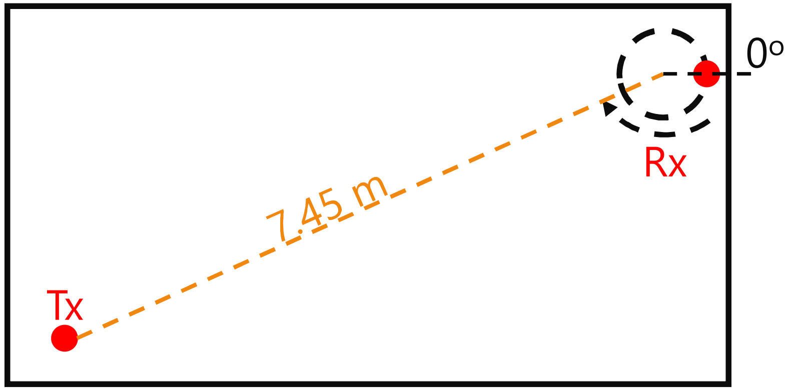
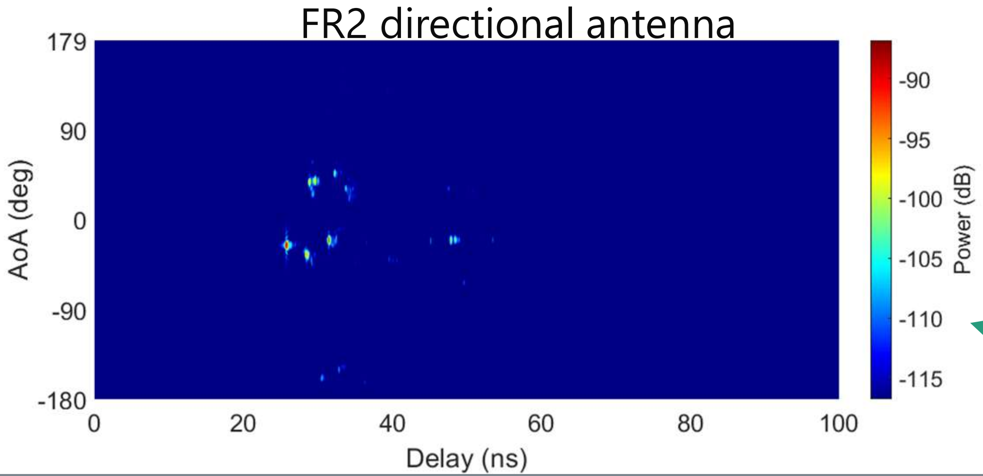


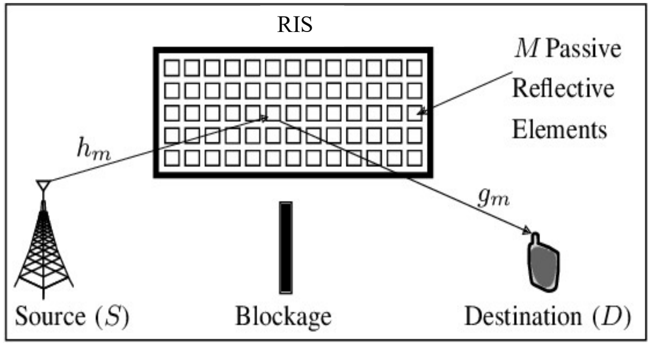
Parameter	Omni Value	Dir Value
Frequency	2-30 GHz	26.5-40 GHz
Number of points	15001	7001
IF bandwidth	500 Hz	500 Hz
Transmitted power	0 dBm	0 dBm
Radius of the UCA	18 cm	11.5 cm
Rotation step	2 degree	1 deg

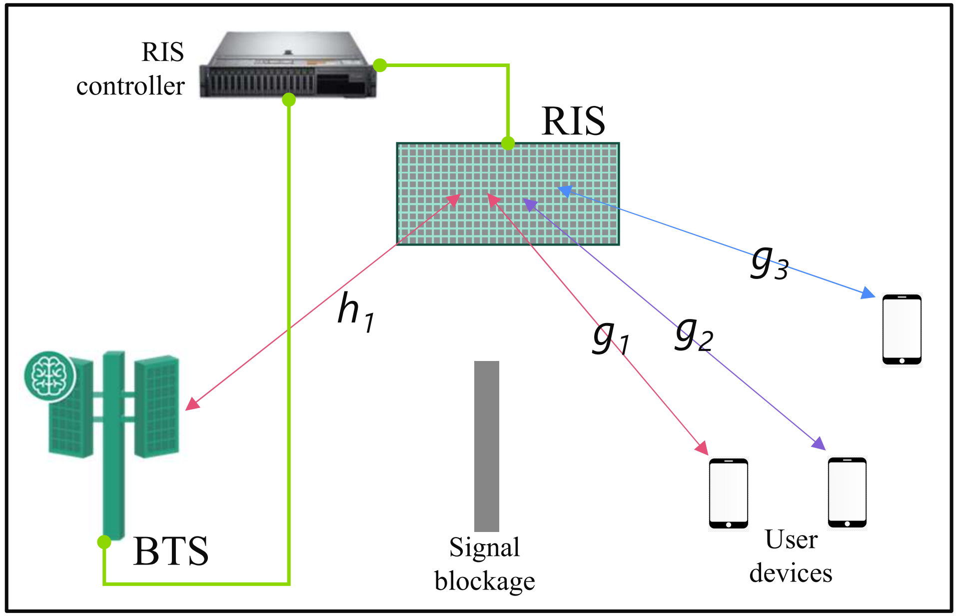


LoS distance =7.6 m
LoS path power after CBF: -86.8 dB
DSS result: -86.4 dB

Accurate map of reflections
(in-building sensing and location)

Reconfigurable Intelligent Surfaces (RIS)



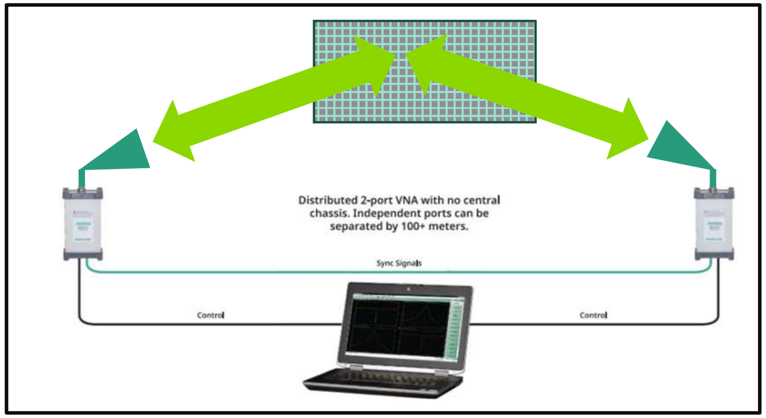


Theory:

Array of M reflective elements creates reflection g_m from incoming signal path h_m.

Adjustment of the phase response of each element enables the direction of g_m to be adjusted.

BTS signals are coordinated with RIS controller, so that signals to a specific device are reflected in a specific path. Advanced channel sensing allows the determination and adjustment of path g_m.



VNA measurement example:

A VNA is used to send & receive signals across the intelligent surface. Both phase and amplitude of reflected signals are measured (full 2 port measurements, S_{11}, S_{21}, S_{12}, S_{22}) to characterise the reflection.

Small and portable distributed VNA's used in ME7868A can be separated by 100's of metres, and mounted on mechanical positioners to characterise across different angles.

See also: ETSI Industry Specification Group "Reconfigurable Intelligent Surfaces" (ISG RIS)

Status and testing for Artificial Intelligence and Machine Learning (AI/ML).

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AI and ML outline.

Use AI/ML to learn and ‘infer’ a decision, rather than a decision using a fixed algorithm that has been tuned/optimised.

AI is used individually today in applications in Web, Networks, and Devices.

Status and studies in 3GPP.

For Core Network analytics. NWDAF and NEF in 5G SA to provide data sets.

For air interface. New options investigated in Rel18 for improving network functions such as Channel Estimation.

For 6G. Design new protocol stacks, procedures, and interfaces that have AI/ML designed inside of the network functions.

Figure 1: Appling ML to RAN in different time cycles

RAN ML type	Time cycle	Implementation	Example benefits
RAN planning & deployment	Yearly/ monthly	Network design—e.g., to determine placement and configuration of gNBs	Better coverage, greater system capacity, optimized capex, faster deployment
RAN/Core management & optimization	Weekly/daily/ hourly	Ongoing changes to cell or cell cluster configurations—e.g., in response to changes in demand	Enhanced network assurance and performance; better security via anomaly detection
Real-time air interface transmission	Seconds/ milliseconds	L1-L3 radio parameters in the centralized unit (CU), distributed unit (DU), and radio unit (RU)—e.g., to apply new RAN algorithms	Better resource utilization and congestion control, power management, handover optimization, etc.

Source: Heavy Reading

Status and studies in other Telecoms.

ITU-T: Focus Group on Machine Learning for Future Networks. Developing frameworks for ML data collection, modelling, and evaluation

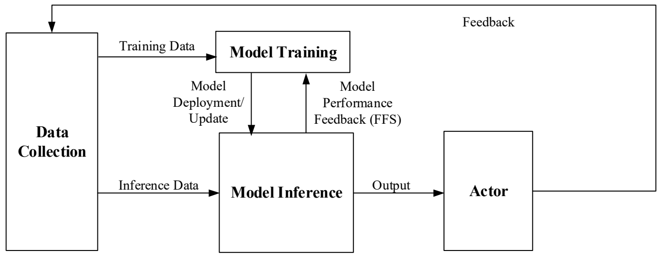
Key issues to address.

The process of ‘learning’: Development and deployment of Training models, building and verifying data sets.

Supervised learning and non-supervised learning (such as reinforcement learning) may need different data sets.

Centralised and Federated learning each have different features and architectures:

- (large amount of data sent across network, versus large amount of processing power on device)



Application #1: AI & ML for test tools.

Use of AI/ML in test solutions. Preparation of test plan (optimise test sequences), analysis of test results (predict issues, discover anomalies).

Application #2: Test tools for AI/ML.

Define KPI’s (what parameters to test and measure).

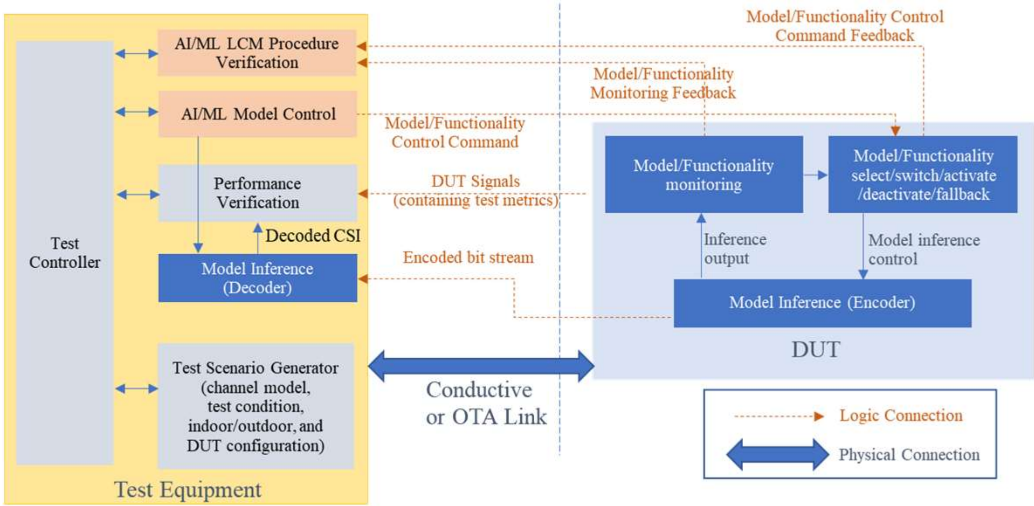
Benchmark methods and test frameworks (how to evaluate), including 2-sided models.

Create training data for learning, validation, and for certification (LCM).

Test & Measurement Application for AI/ML.

New challenges for implementation of "Test Tool for AI/ML".

- Generation of Training Data Sets for learning, testing and validation phases.
- Life Cycle Management (LCM), environment for updating, deploying and executing the Model Training activity.
- Generation and distribution of Data sets for different learning modes (online/offline, supervised, reinforced, centralised, federated, etc).
- Definition, measurement and calculation of new KPI's.
- Implementation of benchmark algorithms (e.g. standardised, or industry standard benchmarks) and 2-sided models.



3GPP RAN4 Proposed reference block diagram for 2-sided model test.

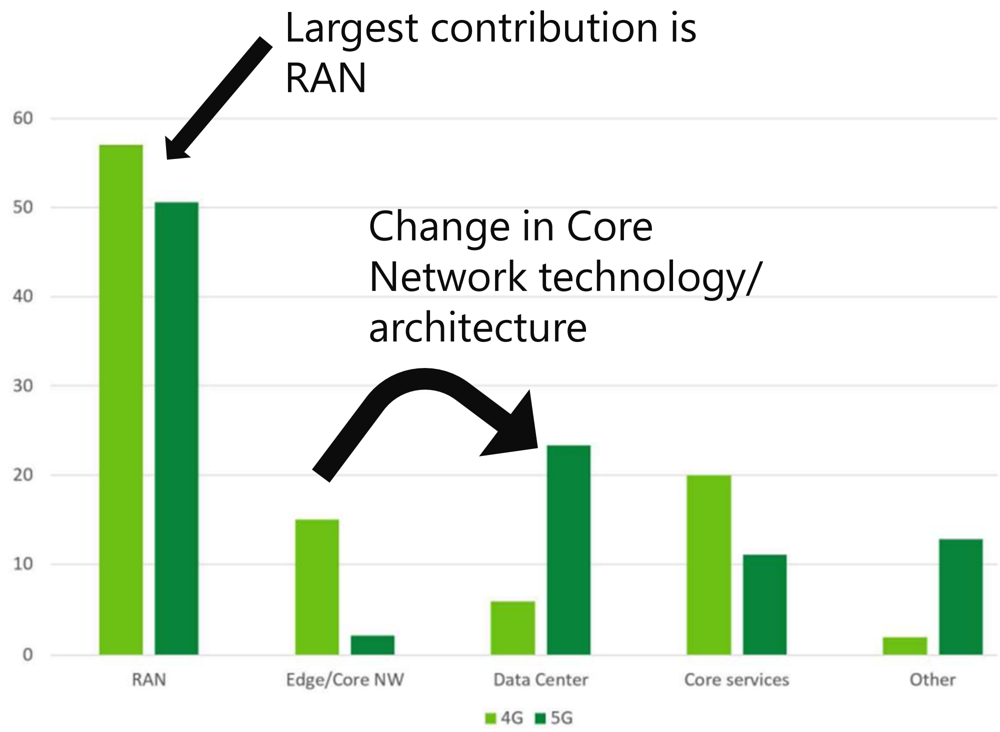
Energy Consumption Per Network Components

- According to the report from GSMA, the energy cost on mobile networks accounts for ~23% of the total operator cost

- Networks Supporting
  - 16 x throughput
  - 5 x more bandwidth
  - 4 x more consumption (2-3x smaller cells)

- RAN Consumption 70% network
  - mmWave transceivers
  - Massive MIMO
  - PA efficiency
  - Base station load
  - Sleep states
  - Transition times

- Data Center Power Consumption Rising
  - Move from dedicated core NW to virtualised networks.



Anritsu current 6G research tools portfolio

MS4647B/ME7838G <u>220 GHz broadband Vector Network Analyser (with SpA option).</u>

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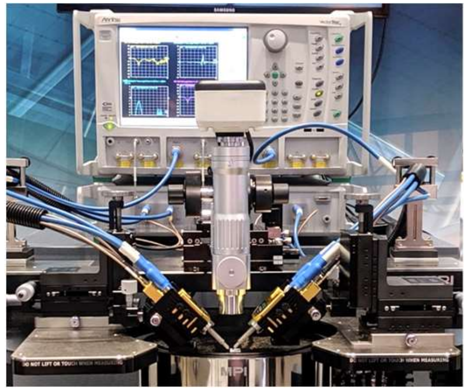
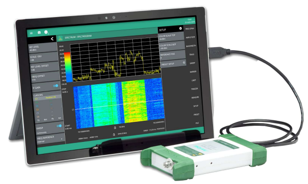


MS2760A/MS2762A <u>Ultra-portable swept spectrum analyser to 170GHz</u>

Support all bands including 'D-band' for OTA and device/component testing.

Ultra compact solution for lab, chamber, field trials etc.

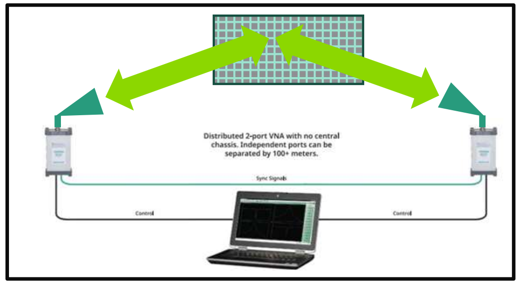


ME7868A/ME7869A <u>PhaseLync distributed VNA up to 43GHz</u>.

Full 2 port reversing VNA measurements with phase locked separate units.

Compact and portable, with separation of over 100m.

RIS characterisation, channel sounding, chamber calibration, etc.



Beyond 5G & 6G: Market Trend Summary.

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- **Beyond 5G & 6G Use Cases not clear yet, only just starting to define them.**
  - Industry and academia is evaluating the progress of '5G Advanced', to see the possible evolution 'beyond 5G'.
  - 6G target is to bring capabilities not possible in 5G based wireless cellular technology.
  - Business Value -> Societal Value. 6G may have a wider scope than 5G use cases.
  - Environmental impact, Energy Efficiency, and 'Green' issues become an important priority.

- **Central themes for Use Case proposals:**
  - Digital Twin, physical/digital/biological worlds converge. (Cyber-Physical Convergence.)
  - Real time immersive 3D experiences, full Holographic images.

From NGMN white paper

- **Fundamental Technology evolutions:**
  - Terahertz Frequencies.
    - Modulation and Coding schemes for wide band, channel modelling, MIMO evolution.
  - Spectrum Efficiency at FR1/FR2, and new frequencies in 'FR3' (7-24GHz)
    - Virtual MIMO, full duplex, advanced spectrum sharing, RIS.
    - AI and ML designed native into air interface and cellular architecture. Embedded native into O&M, orchestration, etc.
  - Integrated Sensing and Communications (ISAC) to enable new use cases using telecoms waveforms and frequencies.
  - Dis-aggregated networks and Distributed Computing to share massive computing power (cloud, AI, etc).
    - Utilise cloud native RAN for more flexible processing, (e.g. dynamic share across UE/RAN/Core.)
  - Optical network technologies to enhance network efficiency, data rate and latency.
    - All Photonic Network, On-Board Optics, and Silicon Photonics.

- **Test & Measurement technology will advance in line with these Fundamental Technology evolutions.**