6GTandem White Paper: Strengthening Sub-THz Wireless Systems through Dual-Frequency Distributed Deployment

Technical white paper based on 6GTandem Deliverable D6.3: Key exploitable results, exploitation roadmap, standardisation approach and scientific output

6GTandem Consortium (6GTandem, SNS JU, Grant Agreement No. 101096302)

Executive Summary

6GTandem developed and validated a dual-frequency distributed deployment concept for future high-capacity wireless infrastructures. The approach combines a robust sub-10 GHz layer with a high-capacity sub-THz layer in the D-band (110 to 170 GHz). It addresses a central question for next-generation wireless connectivity: how can very large sub-THz bandwidths be exploited without losing service reliability in indoor environments shaped by blockage, mobility, hardware impairments and deployment constraints?

The project's core results emerge from the co-design of network topology and operation procedures with hardware solutions for a sub-THz radio stripe-based deployment. A central unit transmit D-band signals over polymer microwave fibre (PMF) to radio units distributed in the coverage space. This enables dense deployment of sub-THz signals, while the sub-10 GHz layer provides coverage, control-plane robustness, positioning support and fallback operation. 6GTandem validated the main building blocks for this concept, including D-band transmitter and receiver circuits, Embedded Wafer Level Ball Grid Array (eWLB)-based packaging, antenna-in-package modules, PMF couplers, high-data-rate PMF links, positioning-assisted radio unit selection and hardware-aware simulation tools.

This white paper presents the public technical exploitation perspective of 6GTandem. It consolidates the key exploitable results, exploitation roadmap, standardisation approach and scientific output of the project. The main conclusion of 6GTandem is that the combination of dual-frequency operation, distributed radio stripe deployment and advanced D-band hardware technologies offers significant potential to overcome key barriers to reliable sub-THz wireless connectivity. The project achieved major technological progress at both hardware and system level, by demonstrating very high-throughput links together with the development of dual-frequency concepts that enable reliable coverage.

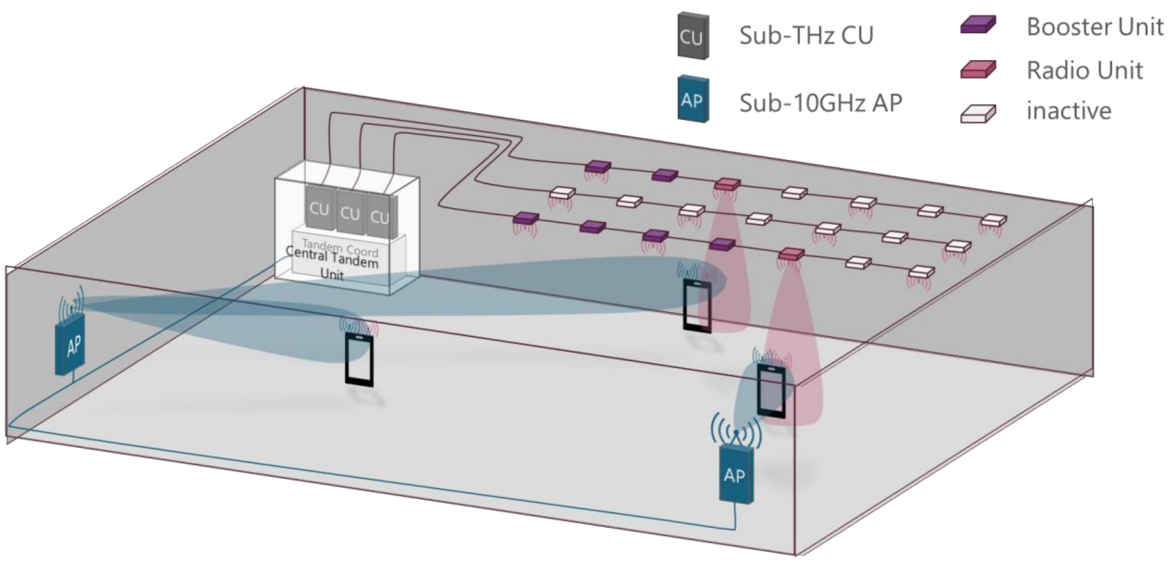

Figure 1: Distributed deployment and dual-frequency operation architecture of 6GTandem

1. Introduction

Future wireless systems are expected to support extreme data rates, precise localisation, immersive services and dense indoor connectivity. Sub-THz frequencies offer the bandwidth needed for these capabilities, but their use in access networks remains technically demanding. D-band[1] links are highly directional, sensitive to blockage and strongly constrained by hardware limitations such as output power, phase noise, nonlinearities, coupling losses and packaging complexity. These factors determine whether high-frequency wireless access can move beyond controlled laboratory demonstrations.

6GTandem addresses these challenges through a tandem architecture with two complementary frequency layers. The sub-10 GHz layer provides reliable connectivity, positioning support and control-plane stability. The sub-THz layer delivers high-capacity transmission whenever propagation conditions allow it. This creates frequency diversity and enables graceful fallback when sub-THz links are blocked or unavailable. The radio stripe concept adds spatial diversity by distributing radio units along infrastructure that can be integrated into ceilings, walls, industrial halls, transport hubs and other dense environments. These architectural principles are reflected in the project's work on dual-frequency concepts, radio unit selection and timing advance estimation [1]-[3].

The project produced exploitable results at component, system, algorithmic and methodological level. These include integrated D-band transceivers, PMF-based signal distribution, antenna-in-package modules, cross-layer algorithms, positioning-assisted radio unit selection, waveform and impairment models, and open research assets such as simulation tools and datasets. Together, they form a technical basis for follow-up research, industrial evaluation, pre-standardisation contributions and product-oriented development.

Key messages

- **Sub-THz wireless links need reliability, not only bandwidth.** D-band communication can deliver very high data rates, but practical deployment depends on resilience against blockage, mobility and hardware impairments.
- **Dual-frequency operation can strengthen sub-THz connectivity.** Combining a robust sub-10 GHz layer with an opportunistic sub-THz layer provides fallback, positioning support and control-plane stability.
- **Radio stripes offer a scalable deployment concept.** Distributed radio units connected through polymer microwave fibre can bring high-capacity sub-THz signals close to users in dense indoor environments.
- **Validated building blocks are ready for further maturation.** 6GTandem demonstrated D-band transceivers, antenna-in-package modules, PMF links, cross-layer algorithms and hardware-aware simulation tools.
- **Standardisation should follow evidence.** The project's recommendation regarding standardisation is to strengthen sub-THz systems first and standardise them once deployment possibilities, robustness and realistic evaluation assumptions are sufficiently validated.

2. Technical Basis: Key Exploitable Results

The key exploitable results of 6GTandem cover the technology stack required for dual-frequency distributed operation. They include architectural concepts, hardware building blocks, algorithms, models, tools and methodological know-how. Their value lies in the integrated evidence they provide on the feasibility, limits and development needs of sub-THz radio stripe systems.

[1] Terminology note: Sub-THz denotes the broader system context, whereas D-band refers to the specific frequency range and hardware implementations validated in 6GTandem.

Table 1: Key Exploitable Results of 6GTandem

Key exploitable result	Technical contribution	Validated status	Exploitation relevance
Dual-frequency distributed architecture (sub-10 GHz + sub-THz tandem concept) [1]	Coordinated sub-10 GHz and sub-THz operation for reliable control, positioning, fallback and opportunistic high-capacity transmission in indoor environments.	Validated through system modelling, simulation and four demonstrator scenarios.	Foundation for resilient high-frequency wireless connectivity and pre-standardisation studies.
D-band circuits: transceivers (TX/RX, full D-band coverage), amplifiers, phase shifters, active switches [13], [15], [29]	Fully functional integrated transmitter and receiver in Infineon B12HFC SiGe-BiCMOS covering 110–170 GHz, plus power amplifiers exceeding 10 dBm, low-noise amplifiers, mixers, switches and phase shifters.	All circuits have been validated through on wafer measurement and all of them are functional. Functional D-band TX/RX modules with TX peak output of 4 dBm; standalone PA exceeding 10 dBm.	Relevant for telecom infrastructure, fixed wireless connectivity, fronthaul and automotive high-frequency applications.
eWLB packaging technology for D-band [4], [5], [12]	Embedded wafer-level ball grid array packages with passive structures (CPW lines at ~0.4 dB/mm, baluns at 1–1.5 dB) fabricated and characterised across two tape-outs.	Two eWLB tape-outs completed; passive and active structures characterised up to 170 GHz.	Enables scalable, cost-effective D-band module production for telecom, automotive radar and sensing applications.
Antenna-in-Package (AiP) modules (single element and array) [8], [9], [16], [25], [28]	Compact circularly polarised D-band antenna elements and four-element arrays are designed and integrated in eWLB package technology.	Single-element and four-element AiP modules characterised with measured radiation patterns matching simulation within 135–155 GHz.	Basis for compact D-band radio units, beam steering and future multi-element arrays.
PMF couplers (Vivaldi and inverted Vivaldi designs) [4], [5], [12]	Standard and inverted Vivaldi coupler designs integrated in eWLB, interfacing sub-THz signals between packaged circuits and polymer microwave fibre.	Measured insertion loss of 1.7–3 dB up to 150 GHz for both coupler variants.	Critical interface component for radio stripe assembly; enables modular PMF-to-chip connectivity.
Polymer microwave fibre (PMF) technology and launcher [11]	Fibre development including NiCu-tape cladding treatment reducing ripple by an order of magnitude, PVD coating extended to 5 m, and new integrated PMF with launcher for radio stripe integration.	100 Gbps over 1 m PMF and 80 Gbps over 2.8 m PMF demonstrated with eWLB-packaged TX/RX modules.	Potential basis for active radio stripes and high-capacity short-reach interconnect products.
Radio stripe building blocks (CU, BU, RU modules) [6], [26]	Complete signal path modules including central unit (CU), booster unit (BU) (0–2 dB gain within 120–150 GHz) and radio unit (RU) for serial sub-THz distribution and over-the-air transmission.	CU demonstrated 100 Gbps over 1 m PMF link; RU demonstrated 4 Gbps (16-QAM) over the air; BU validated within 120–150 GHz.	Modular building blocks for scalable radio stripe deployment in indoor high-capacity scenarios.
Design environment and PDK (B12HFC SiGe-BiCMOS)	Process design kit and circuit design environment for Infineon's B12HFC SiGe-BiCMOS technology, supporting D-band circuit development.	Used to design and fabricate functional TX/RX circuits covering 110–170 GHz.	Reusable design infrastructure for D-band and sub-THz circuit development beyond the project.
Cross-layer dual-frequency algorithms (RU selection, timing	Deep-learning-based radio unit selection using sub-10 GHz channel information, learning-	Validated through hardware-aware simulation and	Supports robust sub-THz connectivity, reduced beam

advance, offloading) [2], [3]	based timing advance estimation, and dual-band resource coordination.	demonstrator-related scenarios.	scanning overhead and smoother RU handover.
6GTandem simulation framework and models [10], [17], [18], [19], [20]	Modular simulation environment integrating propagation, mobility, traffic, hardware impairments (nonlinearities, phase noise, PMF losses) and dual-frequency coordination.	Used to evaluate deployment scenarios and system behaviour under realistic constraints across all work packages.	Reusable research asset for follow-up R&D, benchmarking and pre-standardisation evidence building.
Waveform evaluation for cascaded PMF+PA systems [7], [10], [11], [14], [17]	Systematic evaluation of candidate waveforms (CP-OFDM, SC-FDE, DFT-s-OFDM) under realistic radio-stripe impairments including PMF propagation and cascaded amplifier effects.	Optimal input back-off, modulation order and waveform configuration identified through simulation.	Informs waveform selection for future sub-THz standards and radio stripe system design.
Cascaded PA optimisation and DPD algorithms [14], [17], [22], [27]	Analytical models and digital predistortion methods for nonlinear distortion in cascaded amplifier chains along the radio stripe.	Validated through simulation with hardware-aligned parameters; DPD shown to reduce out-of-band emissions.	Supports efficient amplifier operation in distributed sub-THz systems and feeds into pre-standardisation.
Phase noise analysis at D-band	Models for phase-noise effects in D-band operation including the impact of frequency multiplication chains with factor sixteen.	Analytical expressions derived and validated through simulation for phase noise at 140 GHz.	Supports realistic oscillator and link design for future D-band systems.
Dual-band data traffic offloading optimisation [1]–[3]	Optimisation methods for allocating eMBB and URLLC traffic across the sub-10 GHz and sub-THz layers based on channel conditions and QoS requirements.	Validated through system-level simulation in dual-frequency deployment scenarios.	Provides resource management strategies for dual-band 6G networks with mixed traffic types.
Sub-10 GHz positioning for sub-THz RU selection [2], [3], [7], [10]	Positioning approach based on sub-10 GHz access points to guide sub-THz radio unit selection and reduce reliance on exhaustive high-band scanning.	Sub-10 GHz positioning accuracy below 10 cm RMSE demonstrated in office environment with maximum error of 25 cm using three access points.	Enables more reliable high-frequency access in dynamic indoor environments.
XR mobility dataset [20], [23], [24]	Publicly available dataset of user movement in immersive XR environments capturing head, hand and body tracking data from 33 volunteers across three VR applications.	Dataset released and used for mobility-aware system evaluation within the project. (6DoF, 33 users, 45 hours)	Open research asset for XR-aware network planning, beam management studies and mobility modelling.
Link budget methodology for fibre-distributed sub-THz systems [4]–[6], [10]–[12], [18], [26]	End-to-end link budget methods covering the PMF-based distribution path and the over-the-air D-band link, accounting for all relevant hardware impairments.	Applied to evaluate demonstrator configurations and system design trade-offs. Validated through system-level simulation.	Reusable planning tool for dimensioning future radio stripe deployments and sub-THz connectivity links.

2.1 Dual-frequency distributed architecture

The dual-frequency architecture is the system-level foundation of 6GTandem (Figure 1). It coordinates sub-10 GHz and sub-THz operation in one deployment concept. The lower-frequency layer provides coverage, user tracking, positioning and control-plane support. The sub-THz layer provides high-throughput transmission under favourable line-of-sight or near-line-of-sight conditions. This separation

directly addresses the fragility of sub-THz links and offers a practical route toward reliable high-capacity wireless access [1].
The concept was evaluated through a modular simulation framework[2] [18] that models the signal chain from the central unit through the PMF infrastructure to distributed radio units. The framework combines sub-THz and sub-10 GHz propagation, traffic assumptions, mobility information and hardware impairments, including amplifier nonlinearities, phase noise, PMF dispersion, coupler losses and quantisation effects. It supports evaluation of deployment scenarios, radio unit selection, dual-band traffic offloading and hardware-aware system behaviour.

2.2 Radio stripe hardware and PMF signal distribution

The radio stripe concept was realised through a set of hardware building blocks (Figure 2). A central unit generates sub-THz signals and distributes them along polymer microwave fibre to radio units distributed over the coverage space. This topology targets dense deployments and reduces the distance between access points and user equipment, thereby mitigating the path loss and blockage sensitivity that limit standalone sub-THz connectivity. The PMF and radio-over-fibre aspects are supported by project publications on PMF couplers, PMF links, cascaded radio-over-fibre structures, PMF ripple mitigation and next-generation PMF coupler developments [4]–[6], [11], [12],[26].
The project demonstrated integrated transmitter and receiver circuits covering entire D-band spectrum, eWLB-packaged modules, antenna-in-package solutions, PMF couplers and high-capacity PMF links. A 100 Gbps data link over a 1 m PMF section was achieved using 16-QAM modulation, while earlier measurements showed 80 Gbps over 2.8 m PMF. Over-the-air transmission was demonstrated with antenna-in-package modules, including 24 Gbps with a four-element array and 16 Gbps with a single antenna element under laboratory conditions.
PMF technology is a particularly relevant exploitable result because it may provide a short-reach, high-frequency signal distribution alternative to conventional copper or optical interconnects. 6GTandem advanced fibre design, cladding treatment, coating processes and launcher concepts. A new launcher removed the need for precision manipulators and improved coupling stability, while PVD coating capability was extended to 5 m cable length. Further exploitation requires lower PMF loss, improved bend performance, practical connection interfaces and validation of longer radio stripe chains.

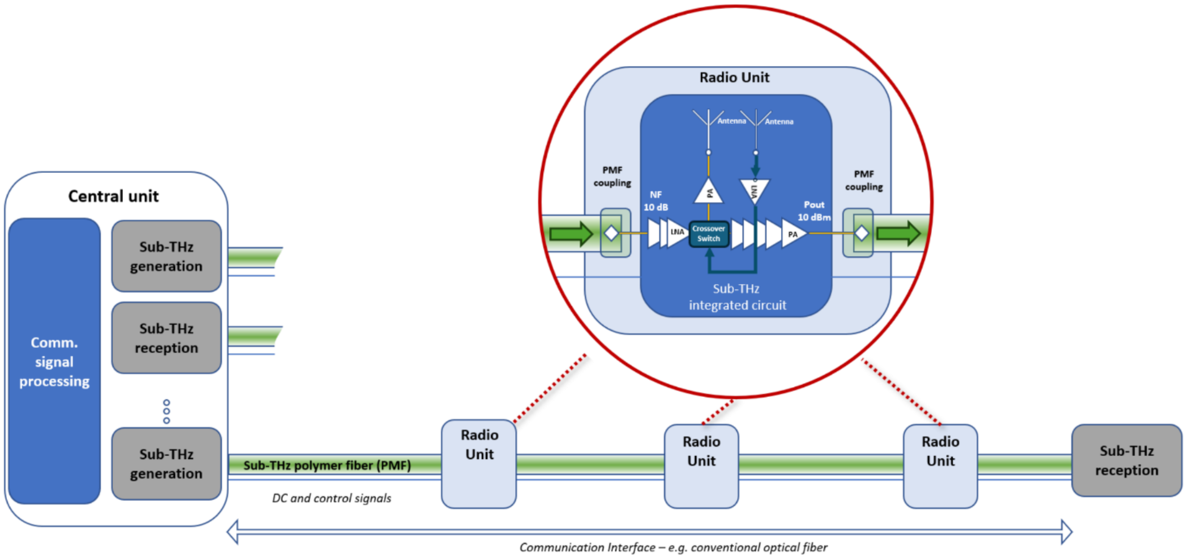

Figure 2: Radio stripe signal distribution with PMF-fed D-band radio units and sub-10 GHz support layer.

[2] https://github.com/6GTandem

2.3 D-band integration, packaging and antenna technologies

6GTandem generated exploitable know-how in D-band semiconductor and packaging integration. The project validated transmitter, receiver, amplifier, mixer, switch and phase-shifter components in SiGe-BiCMOS technology and implemented packaging concepts suitable for sub-THz operation. Embedded wafer-level ball grid array packaging was used to integrate passive structures, couplers and antenna-in-package elements, with measurements feeding back into model refinement and future design improvements. These results are reflected in publications on D-band antenna-in-package concepts, scalable and low-cost D-band antennas, PMF couplers, high-data-rate PMF links and D-band mixer design [4]–[6], [8], [9], [12], [15], [16], [25], [26], [28].

The antenna-in-package work demonstrated single-element and four-element circularly polarised D-band antennas with measured radiation patterns matching simulation in the 135 to 155 GHz range. This confirms the feasibility of compact D-band antenna integration and provides a basis for future multi-element arrays, beam steering and manufacturing yield improvements. The results are relevant for telecommunications infrastructure, automotive connectivity and high-frequency interconnect applications.

2.4 Algorithms, models and tools

6GTandem developed algorithms that use the robust sub-10 GHz layer to support sub-THz operation. A deep-learning-based radio unit selection method predicts the most suitable sub-THz radio unit from sub-10 GHz channel information, reducing the need for direct sub-THz measurement and beam scanning. A related timing advance estimation method supports smoother radio unit handover and reduces additional synchronisation signalling. Dual-band traffic offloading methods allocate enhanced mobile broadband and ultra-reliable low-latency traffic across the lower and higher frequency layers. These algorithmic directions are supported by project publications on radio unit selection and timing advance estimation [2], [3].

The modelling results include cascaded power amplifier models, waveform evaluation under PMF and amplifier impairments, phase noise analysis at D-band and hardware-aware link budget methodologies. These outputs translate component-level limitations into system-level performance constraints. They are therefore valuable for future design work and for pre-standardisation activities that require realistic assumptions instead of idealised RF baselines. Related project publications address cascaded power amplifier modelling, energy-efficient GNN-based precoding, quantisation-aware precoding, cascaded radio-over-fibre modelling and hardware-aware simulation [7], [10], [14],[17], [18], [21], [22], [27].

2.5 Demonstrator validation and technology maturity

6GTandem validated its concept through four demonstrators (Figure 3) covering dual-frequency coverage and radio unit selection in an industrial hall scenario, ultra-high-data-rate PMF and over-the-air links, positioning-assisted sub-THz radio unit selection, and wireless sub-THz fronthaul. The demonstrators confirmed building-block maturity, broadly corresponding to TRL 3 to 4 depending on the component and system function. They also clarified the remaining gap between laboratory validation and deployable multi-unit radio stripe systems.

Key achievements include 100 Gbps over a 1 m PMF link, 24 to 25 Gbps over-the-air transmission in laboratory configurations, sub-10 GHz positioning accuracy below 10 cm root mean square error, and a 4 Gbps wireless sub-THz fronthaul demonstration using a transmitter, PMF link, radio unit and receiver with antenna-in-package integration. These results provide credible evidence for further development while identifying the main limitations: output power, over-the-air range, booster gain, PMF losses and the need for fully integrated cascaded chains.

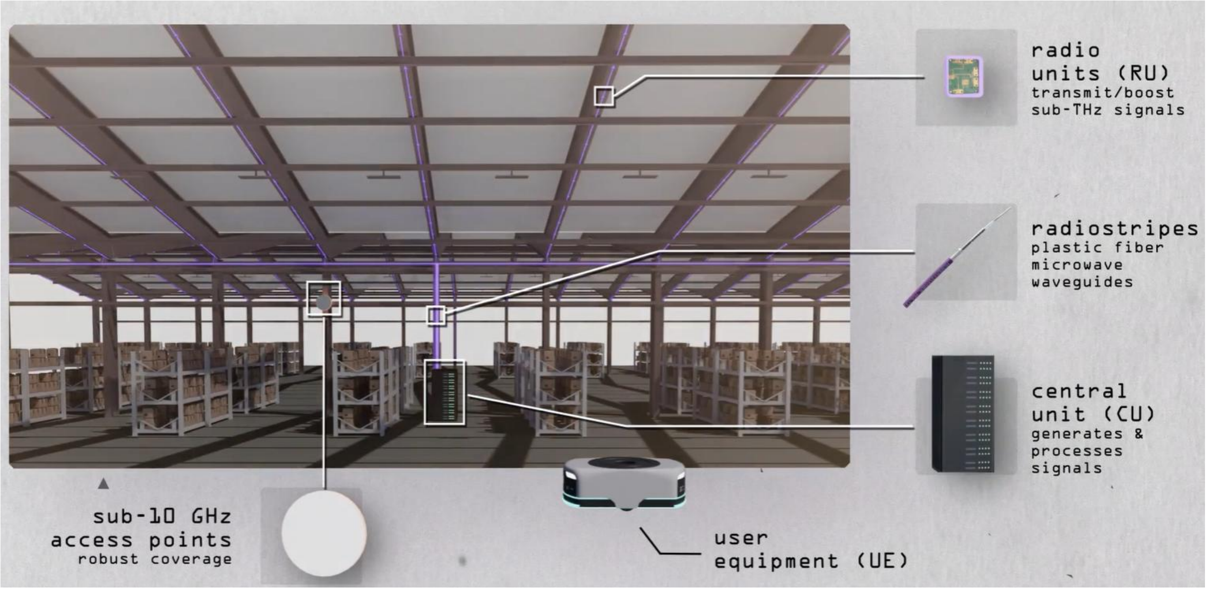

Figure 3: Demonstrator concept of the 6Gtandem validation

3. Exploitation Roadmap

The exploitation roadmap (Figure 4) translates the technical results of 6GTandem into development pathways for research, industrial evaluation, product maturation and future market uptake. The roadmap is staged because the technology is not yet ready for direct commercial deployment. Its immediate value lies in validated building blocks, reusable tools, technical evidence and partner-specific development opportunities.

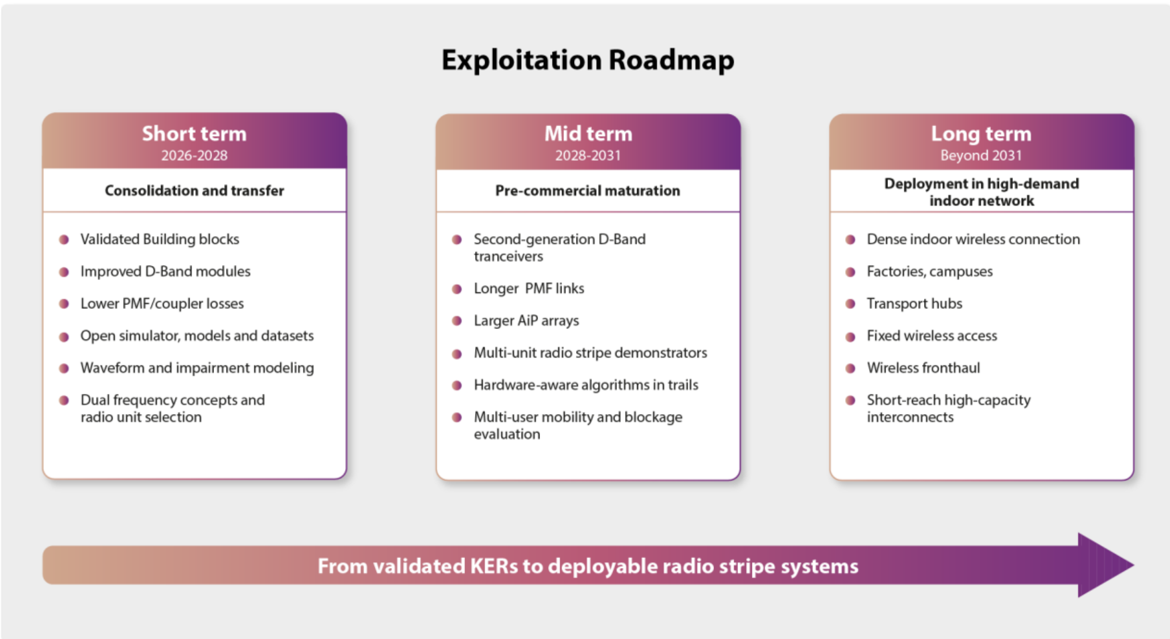

Figure 4: Exploitation roadmap from validated 6GTandem KERs to deployable radio stripe systems

3.1 Short-term exploitation: consolidation and transfer

In the first two years after the project, exploitation should focus on consolidating validated results and transferring them into follow-up research. Hardware technical work should address transmitter module improvements, increased output power, improved booster gain, lower PMF coupler losses and extended over-the-air link performance beyond controlled laboratory configurations. PMF development should continue toward more compact, lower-loss and more robust cable solutions, while D-band circuit and packaging results should be used to refine models, process design kits and future module implementations.

The simulator, XR mobility dataset, demonstrator evidence, dual-frequency concepts and hardware-aware models provide reusable assets for both scientific and industrial exploitation. These results support follow-up research, pre-standardisation activities, educational use, and future technology development across the communication system and hardware domains. In parallel, project results can be further matured through continued development of D-band hardware, PMF technologies, distributed deployment concepts, waveform solutions, and algorithmic approaches for reliable high-frequency connectivity.

3.2 Mid-term exploitation: maturation toward pre-commercial prototypes

Between 2028 and 2031, exploitation should move from validated building blocks toward pre-commercial maturity. This requires second-generation D-band transceivers with higher output power and improved link range, lower-loss PMF solutions for longer links, improved antenna-in-package arrays, practical connector and launcher technologies, and integrated multi-unit radio stripe demonstrations. Communication system-level work should move from simulation to hardware-integrated field trials and should cover multi-user operation, mobility support and dynamic blockage avoidance.

From an application perspective, mid-term exploitation is expected to focus on sub-THz fixed wireless access, wireless fronthaul, short-reach high-capacity interconnects and automotive or in-cabin connectivity concepts. The data centre interconnect segment may offer an earlier opportunity for PMF-based active cable solutions because it relies on short distances and very high throughput. Full wireless connectivity deployments require more extensive system integration, standardisation alignment and spectrum availability.

3.3 Long-term exploitation: deployment in future high-frequency networks

Beyond 2031, radio stripe systems could support commercial wireless network deployments in high-demand indoor environments such as industrial facilities, transport hubs, stadiums, campuses and smart factories. In such deployments, sub-THz capacity would be used opportunistically, while the sub-10 GHz layer would provide robust connectivity and coordination. This long-term vision depends on progress in integrated hardware, fibre losses, energy efficiency, deployment cost, standardisation readiness and field validation.

The strongest exploitation logic is therefore not a single route to one product. 6GTandem provides a portfolio of assets that can mature along different timelines: semiconductor and packaging technologies for D-band products, PMF-based interconnect technologies for short-reach high-data-rate links, deployment concepts, algorithms and tools for dual-frequency system operation, and pre-standardisation evidence for future high-frequency communication systems.

4. Standardisation Approach

The standardisation perspective of 6GTandem is cautious and evidence-based (Figure 5). Sub-THz communication has strong potential, but the project results confirm that deployability cannot be inferred from peak-throughput demonstrations alone. Links at sub-THz frequencies are highly sensitive to blockage, misalignment, mobility and hardware limitations. Standardisation should therefore be preceded by enhancements of reliability, operating conditions, solutions to cope with hardware impairments and practical deployment architectures.

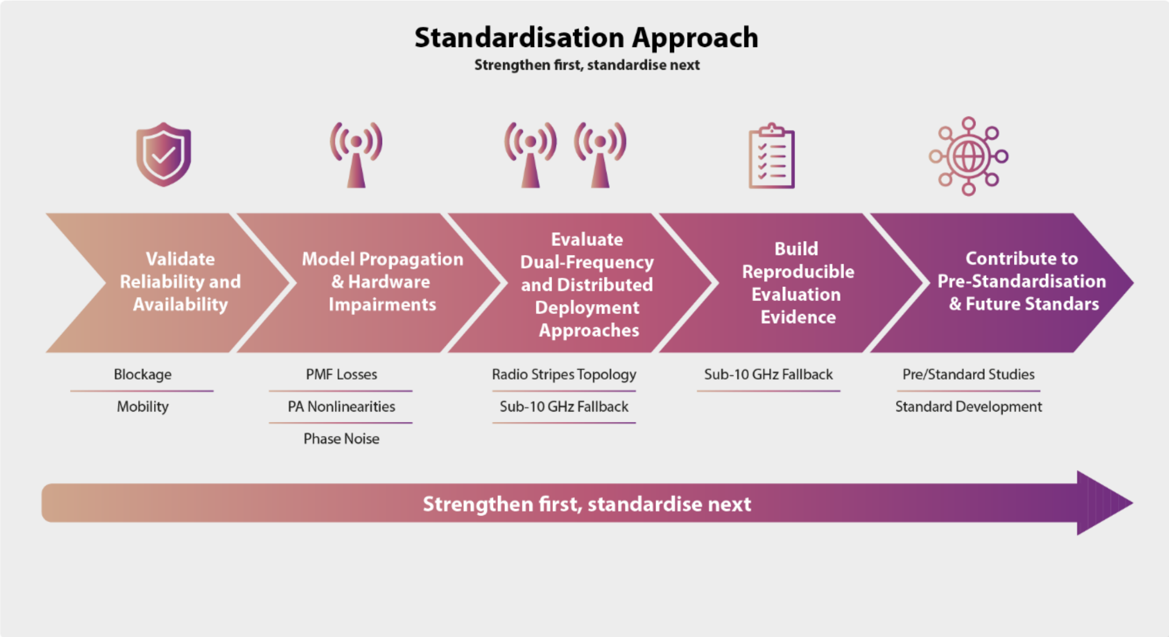

Figure 5: Strengthen-first standardisation pathway from reliability evidence to future sub-THz standards

4.1 Strengthen first, standardise next

The central standardisation message of 6GTandem is: strengthen first, standardise next. The technical community should first develop, validate and compare deployment concepts that make sub-THz operation robust. Normative specifications should follow once these concepts are supported by credible evidence. For 6GTandem, strengthening sub-THz connectivity means combining frequency diversity through sub-10 GHz and sub-THz layers, spatial diversity through distributed deployment, and realistic modelling of hardware and propagation limitations.

This position is grounded in practical observations. Small objects can fully block narrow sub-THz beams (Figure 6), mobility induces rapid channel changes, and high-frequency hardware still suffers from limited efficiency, limited output power and integration constraints. These effects create a gap between laboratory demonstrations and operational wireless connectivity. Future standardisation should therefore prioritise reliability, service availability and deployment options alongside maximum data rates.

Figure 6: The “elephant in the room” for sub-THz standardisation: reliability and deployability must be addressed before normative specifications.

4.2 Pre-standardisation contribution themes

6GTandem results are most relevant to pre-standardisation and study activities. The strongest contribution areas are channel and blockage characterisation, hardware impairment modelling, realistic evaluation frameworks and architecture-level resilience mechanisms. Channel characterisation work can capture outage behaviour, moving blockers, user motion and dynamic indoor geometries. Hardware work should include calibrated parameter sets for nonlinearities, limited output power, phase noise, PMF losses, coupling losses, packaging constraints and energy consumption. Evaluation frameworks should compare systems under access-relevant conditions rather than idealised static links.

The dual-frequency architecture is also a candidate topic for future study because it provides a resilient mechanism for high-band operation. Relevant questions include fallback behaviour, control-plane stability, scheduling across frequency layers, positioning-assisted beam and radio unit selection, and the system-level value of distributed antenna placement. The radio stripe concept raises additional questions on radio-over-fibre or fibre-like distribution, impairment accumulation, deployment topology and interoperability of high-frequency front-end building blocks. These questions are addressed directly by project work on distributed deployment, radio unit selection, timing advance and radio-over-fibre positioning [1]-[3], [7], [10], [17], [22].

4.3 Relevant channels

The most relevant near-term channels are ETSI Industry Specification Groups addressing frequencies beyond 90 GHz, including millimetre-wave transmission and THz-related activities, as well as 6G-IA working groups dealing with pre-standardisation, spectrum and cross-project alignment. Within these channels, 6GTandem can contribute validated evidence, models and methodological recommendations.

5. Scientific Output and Knowledge Transfer

Scientific dissemination is a major exploitation channel for 6GTandem. By the end of the project, the consortium had produced a substantial publication record across journals, magazines and international conferences. The outputs cover wireless infrastructure architectures, radio unit selection algorithms, positioning, signal processing, waveform evaluation, power amplifier modelling, D-band circuits, antenna-in-package technologies and designs, PMF links, open datasets and simulation environments.

The publication record (List of **References**) reflects the multidisciplinary character of the project. System and communication-focused publications addressed distributed deployment, dual-frequency operation, radio unit selection, timing advance estimation and traffic offloading. Hardware publications covered D-band mixer and transceiver design, PMF couplers, antenna-in-package concepts and prototypes and high-data-rate PMF links. Signal processing contributions addressed nonlinear power amplifier effects, graph neural network precoding, waveform optimisation and distortion-aware methods. Dataset and testbed publications supported reproducibility and open research practices.

The project exceeded its original publication targets and continues to generate accepted or submitted papers beyond the formal reporting cut-off. Scientific exploitation will therefore continue after the project end. The open-source simulator, XR mobility dataset, demonstrator evidence and demonstrator videos[3] further strengthen knowledge transfer by making tools, evidence and concepts accessible to the wider research community.

6. Conclusions

6GTandem has established a technically credible foundation for exploiting dual-frequency distributed deployment and sub-THz radio stripe technologies. The project showed that sub-THz communication can deliver very high data rates when supported by suitable D-band hardware, packaging, PMF distribution, antenna integration and signal processing. It also showed that practical deployment depends

[3] https://vimeo.com/showcase/6gtandem-video-showcase

on more than peak link performance. Reliability, blockage resilience, hardware-aware modelling, energy efficiency, deployment cost and integration into broader network architectures are decisive factors.

The main contribution of 6GTandem is the integrated co-design of communication-system concepts, algorithms and hardware solutions that demonstrate promising pathways towards reliable sub-THz wireless connectivity. Through the combination of dual-frequency operation, distributed radio-stripe deployment, advanced D-band hardware technologies and hardware-aware system design, the project generated evidence that key limitations related to blockage, mobility and implementation constraints can be effectively mitigated. Building on these results, the exploitation and standardization pathways presented in this white paper identify opportunities for further maturation of the developed technologies, concepts and methods.

The overall main insight is that dual-frequency operational approaches, the progressed distributed deployment concepts and advanced hardware solutions bear an interesting potential to overcome major barriers to reliable sub-THz wireless connectivity. Still, further R&D efforts are needed to progress the concepts towards actual trials and to raise the confidence level. 6GTandem has established a foundation of validated hardware, algorithms, models and deployment concepts that can support future research, technology maturation and pre-standardisation activities. By demonstrating the benefits of jointly designing communication-system concepts and hardware solutions, the project provides a strong basis for the continued development of high-frequency wireless systems and their future deployment in demanding application scenarios.

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