DATA MANAGEMENT PLAN

Grant Agreement number	21NRM03
Project short name	MEWS
Project full title	Metrology for emerging wireless standards
Data management plan	1st ☐ 2nd ☒
Confidentiality status	PU - Public, fully open

TABLE OF CONTENTS

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The project has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States.

1 Data management plan

1.1 Data summary

Questions	Answers
1 Will you re-use any existing data and what will you re-use them for? State the reasons if re-use of any existing data has been considered but discarded.	This project re-used • Internal data from the participants Data was used for the following purposes: Instrument calibration, measurement correction and validation
2 What types and formats of data will the project generate or re-use?	The project collected: • Text format and XML format • Open binary MAT format • Open image PNG format
3 What is the purpose of the data generation or re-use and its relation to the objectives of the project?	*Purpose of the data generation or re-use* The data generated and re-used was from measurements, calibrations, comparisons and validations. They will be used in meeting the project's objectives and in conference and peer-reviewed publications. *Data generated in relation to the objectives of the Project* Data were generated by the consortium in order to meet objectives 1, 2 and 3. Everything related to measurement, calibration, comparison and validation data were results from objectives 1, 2 and 3. The project generated 11 dataset. The purpose of the data generation and its relation to the objectives of the project is specified below: - **5G NR Full Grid Measurements** (Objective 3). Full resource grid measurements of 5G NR downlink transmission. - **5G NR Full Grid Over-the-Air Measurements** (Objective 3). Full resource grid over-the-air measurements of 5G NR downlink tranmission. - **5G NR Base Station Measurements** (Objective 3). 5G Base Station Measurements for different exposure cases and for different times of a day - **Virtual Antenna Array-Based Channel Sounding at 300 GHz: Implementation and Field Measurements** (Objective 2). Effectiveness of the virtual antenna array scheme, by offering significantly improved SNR and spatial resolution compared with the traditional DSS scheme. - **Sub-THz VNA-based Channel Sounder Structure and Channel Measurements at 100 and 300 GHz** (Objective 2). Vector network analyser based channel sounder systems in 75-110 GHz and 220-330 GHz ranges. Channel sounder structure, link budget and system calibration performance. - **Large Virtual Antenna Array-Based Empirical Channel Characterization for Sub-THz Indoor Hall Scenarios** (Objective 2). 100-GHz channel model for the indoor scenario providing an accurate and comprehensive indoor channel characterization, filling the gap in statistical channel models for this frequency band. - **Enabling Long-Range Large-Scale Channel Sounding at Sub-THz Bands: Virtual Array and Radio-Over-Fiber Concepts** (Objective 2).

	Novel directional antenna-based virtual antenna array framework and associated beamforming algorithm. - **Design and Validation of the Phase-Compensated Long-Range Sub-THz VNA-based Channel Sounder** (Objective 2). First vector network analyser based sub-Terahertz phase-compensated channel sounder at 220-330 GHz using radio-over-fiber techniques, enabling long-range phase-coherent measurements. - **Deterministic Ray Tracing: A Promising Approach to THz Channel Modeling in 6G Deployment Scenarios** (Objective 2). Ray tracing based channel modeling approach for describing the propagation characteristics (i.e., the delay and spatial dispersion, channel sparsity, near-field propagation, and non-stationarity) with reduced simulation complexity in THz bands. - **Measurement-based channel characterization in a large hall scenario at 300 GHz** (Objective 2). Analysis of the key propagation channel parameters, e.g., path loss, delay spread, and angular spread. - **330–500 GHz and 500–750 GHz ray tracing** (Objective 2). Ray tracing figures including magnitude, phase and frequency information.
4 What is the expected size of the data that you intend to generate or re-use?	The overall size of the generated data was approximately 7.5 GB.
5 What is the origin/provenance of the data, either generated or re-used?	*Data generated in the project* The data generated was from measurements, calibrations, comparisons and validations. The data collected from domestic properties will remain confidential and will not be included in the repository. The project generated 11 dataset. The provenance of the data generated is specified below: The provenance and context of the data were thoroughly documented to meet relevant standards using the Provenance and Context Content Standard (PCCS) Matrix. The data are accompanied by information on how they were captured, processed, analysed, and validated. Other relevant information was also provided.
6 To whom might your data be useful ('data utility'), outside your project?	The data will be suitable for use by other research groups working on the following topics: OTA measurement and testing, sub-THz channel characterization, RF exposure. It will also be useful for standards committees including CENELEC CLC/TC 106X, IEC TC 106 MT3 and JWG12, IEEE ICES TC95, 3GPP RAN WG4, ETSI mWT and THz ISG, CTIA MOSG and MUSG, IEEE WG 1720, IEEE 802.15 SC THz, ITU-R IMT-2020 and regulators.

1.2 Findable, Accessible, Interoperable and Re-usable (FAIR) Data

1.2.1 Making data findable, including provisions for metadata

Questions	Answers

7 Will data be identified by a persistent identifier?	Yes, each of the project's deposited datasets is identified by: • DOI • Commit/tag on Git repository • Handle • Other
8 Will rich metadata be provided to allow discovery? What metadata will be created? What disciplinary or general standards will be followed? In case metadata standards do not exist in your discipline, please outline what type of metadata will be created and how.	The metadata created for all of the project's deposited datasets was open under a Creative Commons Public Domain Dedication (CC 0) or equivalent (to the extent legitimate interests or constraints are safeguarded), in line with the FAIR principles (in particular machine-actionable) and provide information at least about the following: datasets (description, date of deposit, author(s), venue and embargo); the European Partnership on Metrology funding; grant project name, acronym and number; licensing terms; persistent identifiers for the dataset, the authors involved in the action, and, if possible, for their organisations and the grant. Where applicable, the metadata included persistent identifiers for related publications and other research outputs.
9 Will search keywords be provided in the metadata to optimise the possibility for discovery and then potential re-use?	Yes, the following search keywords were provided in the metadata to optimise the discovery and potential re-use of the deposited datasets: Internet-of-Things, 5G mobile networks, 6G mobile networks, new radio, mm-wave, measurement uncertainty, multiple-input-multiple-output, over-the-air testing, radio frequency exposure, reconfigurable intelligent surface, wireless coexistence communications, calibration, traceability.
10 Will metadata be offered in such a way that it can be harvested and indexed?	Zenodo complies with FAIR principles (https://about.zenodo.org/principles/). The metadata are indexed in a searchable resource. Metadata are licensed under CC0, except for email addresses. All metadata are exported via Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) and can be harvested.

1.2.2 Making data accessible

Questions	**Answers**
Repository:	
11 Will the data be deposited in a trusted repository?	The data were made accessible by deposition in an open access repository. The project's datasets and associated metadata, documentation and code was deposited in Zenodo (https://zenodo.org).
12 Have you explored appropriate arrangements with the identified repository where your data will be deposited?	• No, the data were uploaded via a standard procedure and required no special arrangements.
13 Does the repository ensure that the data are assigned an identifier? Will the repository resolve the identifier to a digital object?	Yes, Zenodo assigned an identifier (DOI) to the project's deposited dataset. The repository resolves the identifier to a digital object.
Data:	
14 Will all data be made openly available? If certain datasets cannot be shared (or need to be	All of the data that were needed to validate the results presented in scientific publications were made openly available as the default. There

Questions	Answers
shared under restricted access conditions), explain why, clearly separating legal and contractual reasons from intentional restrictions. Note that in multi-beneficiary projects it is also possible for specific beneficiaries to keep their data closed if opening their data goes against their legitimate interests or other constraints as per the Grant Agreement.	were reasons not to publish the data that was not included in the publications (see specific reasons below). *Datasets which could not be shared – voluntary restrictions* Other data were not made available on a case-by-case basis as it was not relevant for third parties. The following data were not made publicly available: • Data obtained with the permission of third parties, but the third parties did not agree to make the data publicly available. • Data that disclosed the identity of a manufacturer. Data that compromised the protection of a participant(s) intellectual property. The level of data made available was also considered. Pre-processed data were not provided as there was no clear reason for doing so. *Datasets which could not be shared - legal / contractual reasons* The market / customer survey data, which are commercially sensitive, could not be shared.
15 If an embargo is applied to give time to publish or seek protection of the intellectual property (e.g. patents), specify why and how long this will apply, bearing in mind that research data should be made available as soon as possible.	The data used in scientific publications, posters and oral communications will be made available for re-use as soon as is reasonably possible. Some of the data are expected to be subject to an embargo period of 18 months whilst a patent application is pending. The data used in scientific publications, posters and oral communications was/will be made available for re-use as soon as is reasonably possible. The project has deposited 11 dataset in Zenodo
16 Will the data be accessible through a free and standardised access protocol?	• Yes, Zenodo provides well described conditions for free and standardised access (see http://about.zenodo.org/policies/). • Data will be accessible through Zenodo's REST API https://developers.zenodo.org • The data will be accessible through a free and standardised protocol (such as HTTPS or FTP).
17 If there are restrictions on use, how will access be provided to the data, both during and after the end of the project?	• There are no restrictions on the use of the published data, but users will be required to acknowledge the project and the source of the data in any resulting publications, according to the CC-BY 4.0 license.
18 How will the identity of the person accessing the data be ascertained?	• There is no need to ascertain the identity of persons accessing the data.
19 Is there a need for a data access committee (e.g. to evaluate/approve access requests to personal/sensitive data)?	• This consortium will not establish a Data Access Committee. The coordinator, with support from project participants, will have overall responsibility for the management of data/research outputs and quality assurance. The coordinator will be responsible for

Questions	Answers
	• This consortium did not establish a Data Access Committee. The appointed corresponding author, with responsibility for the data, decided alone about granting access to the data.
Metadata:	
20 Will metadata be made openly available and licensed under a public domain dedication CC0, as per the Grant Agreement? If not, please clarify why. Will metadata contain information to enable the user to access the data?	In Zenodo, metadata are licensed under CC0, except for email addresses. All metadata are exported via OAI-PMH and can be harvested.
21 How long will the data remain available and findable? Will metadata be guaranteed to remain available after data are no longer available?	The data will remain available and findable for the lifetime of the Zenodo repository, which is expected to be a minimum of 20 years. If data are withdrawn from Zenodo, the DOI and the URL of the original object are retained. In case of closure of the Zenodo repository, best efforts will be made by Zenodo to integrate all content into suitable alternative institutional and/or subject based repositories.
22 Will documentation or reference about any software be needed to access or read the data and will this be included? Will it be possible to include the relevant software (e.g. in open source code)?	Data can be read by using openly available formats (ODT, PDF, MS Office). The project's datasets which have been deposited in Zenodo i) are accessible using the following software tools, ii) require the following documentation about the software, and iii) require the following software: i) MS office or free equivalent software. ii) No specialist software is required. iii) Text reader and free *.mat format readers.

1.2.3 Making data interoperable

Questions	Answers
23 What data and metadata vocabularies, standards, formats or methodologies will you follow to make your data interoperable to allow data exchange and re-use within and across disciplines? Will you follow community-endorsed interoperability best practices? Which ones?	The datasets will use the trusted repository's basic metadata schema for administrative data, which is compliant with the recommended standards used by DataCite (https://search.datacite.org/) and OpenAIRE (https://www.basesearch.net/). For individual datasets, the following discipline-specific vocabularies, standards, formats, and methodologies will be used: 1. GUM (procedure; subject-independent). 2. OBO foundry (MD schema; biological sciences). 3. DICOM (MD schema + file format; biomedical imaging). 4. NetCDF (file container format; geographical information). 5. HDF5 (hierarchical file format; subject-independent). 6. CityGML (file format; smart city).

	7. INSPEC (vocabulary + classification; physics). 8. ISO 9001 (QM procedure; subject-independent).
24 In case it is unavoidable that you use uncommon or generate project specific ontologies or vocabularies, will you provide mappings to more commonly used ontologies? Will you openly publish the generated ontologies or vocabularies to allow their re-use, refinement or extension?	• Mapping was not required as the terminology used was chosen to be compatible with the existing literature.
25 Will your data include qualified references[1] to other data (e.g. other data from your project, or datasets from previous research)?	No, the project's dataset do not include any references to other data.

1.2.4 Increase data re-use

Questions	Answers
26 How will you provide documentation needed to validate data analysis and facilitate data re-use (e.g. readme files with information on methodology, codebooks, data cleaning, analyses, variable definitions, units of measurement, etc.)?	A short README file (e.g. Markdown) was provided together with the data, in order to enable data analysis and to facilitate data re-use.
27 Will your data be made freely available in the public domain to permit the widest re-use possible? Will your data be licensed using standard re-use licenses, in line with the obligations set out in the Grant Agreement?	The project's dataset which has been deposited in Zenodo include the following licenses (where necessary): No license is needed.
28 Will the data produced in the project be useable by third parties, in particular after the end of the project?	Any data published in open-access journals will be usable by third parties after the datasets have been deposited in Zenodo. The data that do not relate to peer-reviewed publications will be made available for re-use on a case-by-case basis.
29 Will the provenance of the data be thoroughly documented using the appropriate standards?	Yes, the provenance and context of the data was thoroughly documented to meet relevant standards using the Provenance and Context Content Standard (PCCS) Matrix. Data were accompanied by information on how they were captured, processed, analysed, and validated. Other information was also provided.
30 Describe all relevant data quality assurance processes.	Data quality was assured through repeated and comparison measurements, adherence to standards for data recording, the use of

[1] A qualified reference is a cross-reference that explains its intent. For example, X is regulator of Y is a much more qualified reference than X is associated with Y, or X see also Y. The goal therefore is to create as many meaningful links as possible between (meta)data resources to enrich the contextual knowledge about the data. (Source: https://www.go-fair.org/fair-principles/i3-metadata-include-qualified-references-metadata/)

Questions	Answers
	controlled vocabularies and standard terminology, through the metrological characterisation of the measurement set-ups and through the validation of the data collected. Other quality assurance processes included the provision of test results along with the data and the peer-review of publications based on the data.
31 Further to the FAIR principles, DMPs should also address research outputs other than data, and should carefully consider aspects related to the allocation of resources, data security and ethical aspects.	*Allocation of resources* The costs for making the (data and) other research outputs FAIR was 5 000 € (personnel costs) (see question 34). The costs for making other research outputs FAIR are included in the project's budget and will be claimed if compliant with the Grant Agreement's conditions. The consortium's Data Access Committee had overall responsibility for managing other research outputs (see question 36). Long term preservation was ensured by depositing the other research outputs in repositories. The Data Access Committee decided on a case-by-case basis which other research outputs were deposited and for how long. *Security of other research outputs* All participants are either accredited to, or work in compliance with, the ISO 17025 standard on the "General requirements for the competence of testing and calibration laboratories". The participants stored other research outputs on their organisations' networks, which are protected by firewall, backups etc. Other research outputs were also stored in the project's SharePoint environment, with password-protected login. Deposition in public repositories provides additional security as they have multiple replicas in a distributed file system which is backed up on a nightly basis. This project did not generate sensitive other research outputs. *Ethical aspects* There were issues that could impact on the sharing of other research outputs. • Information relating to other research outputs acquired from third parties, e.g. manufacturers, was not shared without their explicit consent. • Information relating to other research outputs collected by the consortium at commercial sites was not shared without the site owner's explicit consent. Ethical issues were addressed as the project prepared an ethics report. The project did not share other research outputs with identifiable personal information. Sensitive information relating to the other research outputs was collected, separated as soon as possible and kept secure. Please also see the information provided in section 1.3 below.

1.3 Other research outputs

Questions	Answers
32 In addition to the management of data, beneficiaries should also consider and plan for the management of other research outputs that may be generated	No, other research outputs that can be either digital (e.g. software, workflows, protocols, models, etc.) or physical (e.g. new materials, antibodies, reagents, samples, etc.) were released.

Questions	Answers
or re-used throughout their projects. Such outputs can be either digital (e.g. software, workflows, protocols, models, etc.) or physical (e.g. new materials, antibodies, reagents, samples, etc.).	The software developed in the project will be released under a GNU-GPL license. The new calibration methods, and protocols produced by the project will be stored in the Protocol Exchange repository. The management of the IP issues surrounding the new materials that will be developed in the project have been planned for in the project's consortium agreement. The consortium intends to seek patent protection. This project will only re-use existing data and will not re-use any other research outputs.
33 Beneficiaries should consider which of the questions pertaining to FAIR data above, can apply to the management of other research outputs, and should strive to provide sufficient detail on how their research outputs will be managed and shared, or made available for re-use, in line with the FAIR principles.	As far as possible, the FAIR data approaches specified in questions 7-30 above will be applied to the management of this project's other research outputs. This commitment will be met by releasing the new software that will be developed in the project under license, by placing the new calibration methods, and protocols, in a repository and by patenting the new materials that will be developed in the project in line with the requirements of the project's consortium agreement.

1.4 Allocation of resources

Questions	Answers
34 What will the costs be for making data or other research outputs FAIR in your project (e.g. direct and indirect costs related to storage, archiving, re-use, security, etc.) ?	The estimated costs for making the data and other research outputs Findable, Accessible, Interoperable and Re-usable (FAIR) are 5 000 € (personnel costs). These costs have been kept to a minimum by using a free repository (Zenodo) and by making only relevant data and other outputs FAIR.
35 How will these be covered? Note that costs related to research data/output management are eligible as part of the European partnership on metrology grant (if compliant with the Grant Agreement conditions).	The costs for making the data FAIR are included in the project's budget and will be claimed if compliant with the Grant Agreement's conditions.
36 Who will be responsible for data management in your project?	The coordinator, with support from the project participants, had overall responsibility for data management. The coordinator was responsible for coordinating updates to the data management plan. The participant(s) that produced the data were responsible for organising data backup and storage, data archiving and for depositing the data within the repositories (Zenodo).
37 How will long term preservation be ensured? Discuss the necessary resources to accomplish this (costs and potential value, who	Long term preservation was ensured by depositing the data within repositories (Zenodo). There are no costs associated with the long-term preservation of the data in these repositories. The data will increase in value over time because of its fundamental impact in a wide range of applications. It will enable the technologies developed in the project to be taken up by the measurement supply

decides and how, what data will be kept and for how long)?	chain and by standards bodies including CENELEC CLC/TC 106X, IEC TC 106 MT3 and JWG12, IEEE ICES TC95, 3GPP RAN WG4, ETSI mWT and THz ISG, CTIA MOSG and MUSG, IEEE WG 1720, IEEE 802.15 SC THz, ITU-R IMT-2020 and regulators. These standards bodies will need access to the data to justify the robustness of future standards. The data will also be of value as it underpins the results of published datasets. The coordinator will decide on a case by case basis on what data will be kept and for how long.

1.5 Data security

Questions	Answers
38 What provisions are or will be in place for data security (including data recovery as well as secure storage/archiving and transfer of sensitive data)?	*Data recovery and secure storage* All participants are either accredited to, or work in compliance with, the ISO 17025 standard on the "General requirements for the competence of testing and calibration laboratories". The participants stored data on their organisations' networks, which are protected by firewall, backups etc. Data were also stored in the project's SharePoint environment, with password protected login. Deposition in the Zenodo public repository provided additional security as it has multiple replicas in a distributed file system which is backed up on a nightly basis. *Transfer of sensitive data* • This project did not generate sensitive data.
39 Will the data be safely stored in trusted repositories for long term preservation and curation?	Yes, the data will be safely stored in the Zenodo open access repository. Zenodo and the underlying Invenio Framework for digital repositories were designed according to the Open Archival Information Systems (OAIS) reference model. Zenodo is working towards ISO 16363 certification.

1.6 Ethics

Questions	Answers
40 Are there, or could there be, any ethics or legal issues that can have an impact on data sharing? These can also be discussed in the context of the ethics review. If relevant, include references to ethics report(s) and the ethics section in the Annex 1.	There were issues that could impact on data sharing. • Data acquired from third parties, e.g. manufacturers, were not shared without their explicit consent. • Data collected by the consortium at commercial sites were not shared without the site owner's explicit consent. There were issues that could impact on data sharing. Other issues that could impact on data sharing • The data from the market surveys will be made anonymous to comply with the General Data Protection Regulation (GDPR).
41 Will informed consent for data sharing and long-term preservation be included in	Informed consent for data sharing and long-term preservation will be included in the market and customer surveys, but the project has no plans to share data with identifiable personal information. If any sensitive

Questions	Answers
questionnaires dealing with personal data?	data are collected, it will be separated as soon as possible and kept secure.

1.7 Other issues

Questions	Answers
42 Do you, or will you, make use of other national / funder / sectorial / departmental procedures for data management? If yes, which ones (please list and briefly describe them)?	Data management will be compliant with: • The research data policy of the European Partnership on Metrology; • European laws about data security and the protection of privacy (e.g. GDPR); • Institutional guidelines; • Scientific community guidelines.

2 Open science: research data management

Statement	Put an X in the box to confirm	Or, list any exceptions to this
All participants have adhered to the requirements of the project's GA and CA with respect to open science: research data management (GA Article 17 and its Annex 5) for this reporting period	☒	

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Document Control Page

Document Title:	European Partnership on Metrology Contracts Reporting Template 2: Data management plan	
Document Code:	P-CON-TMP-202	Version 1.2
Document Control:	Approved: Programme Manager	2024-11-25

HISTORY OF CHANGES		
VERSION	PUBLICATION DATE	CHANGE
1.0	2023-01-10	• Initial version.
1.1	2023-08-24	• Section 2: Open science: research data management added.
1.2	2024-11-25	• History of changes added. • Confidentiality status moved from footer to main body of cover page. • DMPs no longer required at first periodic reporting.