Minimum Information Model for Dielectric Measurements of Biological Tissues (MINDER)

MINDER Specifications

The below table describes MINDER data properties.

Property: Name of the data item.
Related Concept: The relevant class of the MINDER model (investigation, material, etc.)
Expected Type: String, Boolean, integer, array, so on. An asterisk (*) next to an expected type means the term must be from a controlled vocabulary, the available options of which are listed in the Controlled Vocabulary document.
Unit: Measurement Unit, if relevant.
Description: Definition/explanation of the property.
CN: Cardinality, i.e., the number of times in which a property can occur: *1* indicates a property may occur a maximum of once, *m* permits multiple instances
Requirement Level: Mandatory (M), Optional (O), Recommended (R)

In many cases, a given property may not apply to a specific study. In this case the field can be left blank, or in the case of a property having a controlled vocabulary the “NA” for not applicable option should be selected.
However, if the property does apply to the study but it not available or not known, ‘unknown’ should be noted.

Excel Template Tab	Property (Field Name)	Related Concept	Expected Type	Unit	Description	CN	RL
INVESTIGATION	Investigation Identifier	Investigation	string	-	Unique identifier for each research project. Investigation Identifier (format: 1stAuthorLastName_Publication/StudyYear_Publication/StudyMonth) Each investigation contains only one research project.	1	M
	Research Project Title	Investigation	string	-	The name of the research project.	1	O
	Research Project Description	Investigation	string	-	Descriptive information detailing the research project. Each project may contain multiple experiments.	1	O
	Principal Investigator ORCID	Investigation	numeric	-	16-digit unique researcher identification number. You can register for a number here: https://orcid.org/ Format is XXXX-XXXX-XXXX-XXXX. One ID may be provided for each principal investigator.	m	O
	Principal Investigator ID	Investigation	string	-	Unique ID for each principal investigator (format: LastName_FirstName_MiddleInitial) One ID may be provided for each principal investigator.	m	M
	Principal Investigator Last Name	Investigation	string	-	The last name/surname of the principal investigator involved in carrying out the study. Must be listed for each principal investigator. Multiple principal investigators are possible.	m	M
	Principal Investigator First Name	Investigation	string	-	The first name of the principal investigator involved in carrying out the study. Must be listed for each principal investigator.	m	M
	Principal Investigator Middle Initial(s)	Investigation	string	-	The middle name initial(s) of the principal investigator involved in carrying out the study. May be listed for each principal investigator.	m	O
	Principal Investigator Email	Investigation	string	-	Email address for principal investigator. May be listed for each principal investigator.	m	R
	Principal Investigator Phone	Investigation	numeric	-	Phone number for principal investigator. May be listed for each principal investigator.	m	O
	Principal Investigator Address	Investigation	string	-	Address for principal investigator. May be listed for each principal investigator.	m	O

	Principal Investigator Affiliation	Investigation	string	-	Affiliation of principal investigator. Must be listed for each principal investigator.	m	M
	Institution where study conducted	Investigation	string	-	The institution at which the investigation was carried out. Multiple institutions are possible.	m	M
	Research Project Funding	Investigation	string	-	The funding sources of the research project.	m	O
	Researchers Involved (including PI)	Investigation	string	-	List of researchers involved in the project.	m	O
	Ethical approval	Investigation	Boolean (*)	-	This field indicates whether ethics approval was obtained for the investigation. If no ethical approval was needed e.g. if no biological samples are used, “NA” for non applicable should be selected.	1	O
	Data usage rights	Investigation	string	-	The usage rights for the data and metadata from the investigation should be specified here.	1	O
EXPERIMENT	Experiment Identifier	Study	string	-	Unique identifier for the conducted experiment. There may be multiple experiments within each investigation.	m	M
	Experiment Title	Study	string	-	Title of the experiment conducted. Each experiment has only one title.	1	O
	Measurement Technique	Experiment	string (*)	-	The type of technique used to perform the dielectric measurement. (e.g., measurements may be coaxial-probe based, or transmission line based, etc.). Within each experiment, only one measurement technique is possible. However, an investigation may contain multiple experiments, each of which may use a different measurement technique.	1	M
	Other Measurement Technique (If “Measurement Technique”=other)	Experiment	string	-	The type of measurement technique used, if not one of the listed options.	1	O
	Measurement equipment	Experiment	string	-	The dielectric measurement equipment used, includes VNAs, probes, etc. Each experiment may have only one set of measurement equipment; however, within an investigation there may be	1	M

					multiple experiments each with different measurement equipment types.		
	Cable used to connect measurement equipment	Experiment	Boolean (*)	-	This field indicates whether a cable was used to connect the measurement tool to the measurement recording equipment (e.g., probe to network analyzer).	1	R
	Measurement software	Experiment	string	-	The dielectric measurement software that is used to obtain the dielectric properties from the S11 measurements. May be proprietary or custom. If custom, details should be provided regarding the software operation.	1	R
	Temperature measurement and control equipment	Environment	string	-	Information on the thermometers or temperature probes used to measure material temperatures, and equipment used to control temperature (e.g. water bath). Multiple types of temperature measurement and control equipment may be used within an experiment. Each piece of equipment should be described individually.	m	R
	Accuracy for each temperature measurement or control equipment	Environment	floating point	C, F, K, +/-% (*)	The measurement accuracy of this individual thermometer or temperature probe; or temperature control accuracy. It can be listed in C, F, K, or in +/-% of reading value. Each piece of temperature measurement or control equipment can have its own accuracy, and multiple accuracy values (of different accuracy types/formats) may be entered for each piece of equipment.	m (=<to number of instances of "Temperature Measurement Equipment")	O
	Environmental Conditions	Environment	String	-	Information on environmental conditions during the experiment, e.g., humidity, room temperature, ambient pressure, etc.	m	O
CALIBRA	Time of measurement equipment turn on	Calibration	floating point	h, min, s, less than (min), less than (h), more than (min), more than (h) (*)	This is the time of the measurement equipment turn on. Some types of equipment require a minimum amount of warm up time prior to measurements for accurate data. Note that a single time point, not a range, should be entered. Researchers may wish to define the measurement equipment turn on time as the 0:00 time of the experiment.	1	O

T I O N	Calibration performed?	Calibration	Boolean (*)	-	System calibration is typically performed prior to measurements. Each time calibration is performed, a new calibration instance is used. Each calibration instance includes properties of the type of calibration material, the calibration material temperature, and the calibration time.	m	M
	Calibration Identifier	Calibration	string	-	Each calibration instance should have a unique identifier.	m	M
	if(Calibration performed?=”yes”), Calibration liquid	Calibration	string (*)	-	This property indicates whether this individual calibration is performed on the standard deionised water or with another material. Generally, each calibration can be performed on only one load liquid (the other two calibration standards being open and short circuit). However, if calibration is performed using multiple load materials, they may each be described in the calibration section individually.	m	R
	if(Calibration performed?=”yes”) && “calibration liquid” = “other”	calibration	string	-	If the calibration was not performed with deionised water, provide the calibration material here.	m	R
	if(Calibration performed?=”yes”), Calibration liquid temperature	calibration	floating point	C, F, K (*)	This property indicates the temperature of the material used during this individual calibration.	m	R
	if(Calibration performed?=”yes”), calibration time	calibration	floating point	h, min, s, less than (min), less than (h), more than (min), more than (h) (*)	This property indicates the time that this individual calibration instance was performed at. Note that a single time point, not a range, should be entered.	1	R
	Number of frequency points	Calibration	positive integer	-	Each calibration can correspond only to one set of frequency points. In this field, the number of frequency points used in the calibration should be noted.	1	R

	Frequency scale format	Calibration	string (*)	-	Each calibration can correspond only to one set of points. The frequency scale of the measured dielectric data. Should be provided for each measurement instance. The frequency points across the frequency range may be selected in linear or logarithmic fashion. Alternative selection of frequency points in the frequency range are possible – in this case 'custom' should be selected. If "Custom," need to add more info in array format.	1	O
	If {Scale of individual measurement}= "Custom", the custom scale of the individual measurement	Calibration	array	Hz, kHz, MHz, GHz, THz (*)	The frequency points that make up the custom scale.	1	O
	Measurement power	Calibration	floating point	dBm, mW (*)	The power of the signal from the network analyser for the given measurement.	1	O
	Measurement Intermediate Frequency Bandwidth (IFBW) of individual measurement	Calibration	floating point	Hz, kHz, MHz, GHz, THz (*)	The IFBW of the recording from the network analyser for the given measurement	1	O
	Start Frequency of Measurement Frequency Range	Calibration	Positive Integer	Hz, kHz, MHz, GHz, THz (*)	This field indicates the start point of the frequency range. Each calibration can correspond only to one frequency range.	1	M
	End Frequency of Measurement Frequency Range	Calibration	Positive integer	Hz, kHz, MHz, GHz, THz (*)	This field indicates the end point of the frequency range. Each calibration can correspond only to one frequency range.	1	M
VALIDATION	Validation performed?	Validation Measurement	Boolean (*)	-	A validation measurement, or measurements, may be performed after system calibration to enable measurement error or accuracy calculations. Each time validation is performed, a new validation instance is used. Each validation instance includes properties of the type of validation material, the validation material temperature, and the validation time.	1	R
	Validation Identifier	Validation Measurement	string	-	Unique identifier for each validation instance.	m	M

	if(Validation Performed?)=”Yes”, Validation material	Validation Measurement	string (*)	-	If validation was performed, the type of validation material that was used. Each validation instance (i.e., each validation identifier) corresponds to one validation material.	1	M
	if(Validation Performed?)=”Yes”&&”Validation material” = “other	Validation Measurement	string	-	If validation was performed and the validation material was not one of the standard types, enter the type of validation material here.	1	R
	if(Validation Performed?)=”Yes”, Validation material temperature	Validation Measurement	floating point	C, F, K (*)	If validation was performed, the temperature of the validation material.	1	M
	if(Validation Performed?=”Yes”), Validation time	Validation Measurement	floating point	h, min, s, less than (min), less than (h), more than (min), more than (h) (*)	If validation was performed, the time that the validation measurement was performed at. Note that a single time point, not a range, should be entered.	1	R
	if(Validation Performed?=”Yes”), literature reference for validation material data or model	Validation Measurement	string	-	In this field, the literature reference(s) for the validation material data or model should be provided in standard IEEE referencing format. Multiple references for the validation material properties may be included.	m	R
	if(Validation Performed?=”Yes”), reference to validation data model	Validation Measurement	String/array	unitless, S/m, other	For each validation material, this is the corresponding model validation data. It should be uploaded/stored in array format, or a link to the data location may be provided. Multiple references for the validation material properties may be included.	m	R
	if(Validation Performed?=”Yes”), Reference to Validation data	Validation Measurement	String/array	unitless, S/m, other	For each validation instance (i.e., each individual validation measurement), this is the corresponding measured validation data. It should be uploaded/stored in array format, or a link to the data location may be provided.	1	R
	Type of error calculation (between data and model)	Uncertainty Analysis	String (*)	-	After conducting validation measurements, the data is compared to the known model. The resulting error between the measured and known dielectric properties determine the measurement uncertainty. The type of error calculation includes accuracy, repeatability, and total combined error	m	R

					(TCU). Multiple types of error calculations may be performed for each validation measurement.		
	other type of error calculation (between data and model)	Uncertainty Analysis	String	-	List the type of error calculation performed, if not one of listed options. Multiple types of error calculations may be performed for each validation measurement.	m	R
	Error value	Uncertainty Analysis	Floating point	Unitless, S/m, %, other	The calculated error for the given validation measurement. There may be multiple calculated errors only if multiple types of error calculation methods were used, or if the measured validation data was compared to multiple models.	m	R
SAMPLE	Sample Identifier	Material	String	-	Unique identifier for each sample. An experiment may contain multiple samples.	m	M
	Type of sample	Material	liquid, phantom, biological tissue, other(*)	-	Each sample is of a specific type. The sample type can be liquid (ex: saline, alcohols), phantom (ex: TX151, oil-in-gelatin), or biological tissue (any tissue derived from human or animal sources). If the sample type is not any of these categories the sample type is "other".	1	M
	If (Type of sample in individual measurement) = "Other", other type	Material	string	-	The type of sample, if not liquid, phantom, or biological tissue.	1	R
	If (Type of sample in individual measurement) = "Liquid", liquid type	Material	string	-	The type of liquid sample (ex: saline, alcohol, etc).	1	M
	If (Type of sample in individual measurement) = "Standard Liquid", liquid volume	Material	floating point	uL, mL, cL, dL, L (*)	The volume of the liquid measured.	1	O
	If(Type of sample in individual measurement)= "Phantom", phantom type	Material	string	-	The type of phantom material.	1	M
	If(Type of sample in individual measurement)= "Phantom", phantom composition (recipe)	Material	string	-	If the material is not standard, a list of ingredients or a reference to the material mixture properties may be provided.	1	R

	If(Type of sample in individual measurement) = “Biological Tissue”, tissue source species	Material	string (*)	-	The species source of the biological tissue sample. For example, the sample may be human, porcine, etc.	1	M
	If(Type of sample in individual measurement) = “Biological Tissue”&& tissue source species= “other”, other tissue source species	Material	string	-	The species source of the biological tissue sample if not one of listed options.	1	R
	If(Type of sample in individual measurement) = “Biological Tissue”, tissue source organ/type	Material	string (*)		The organ or body part of the biological tissue sample.	1	M
	If(Type of sample in individual measurement) = “Biological Tissue”, && tissue source organ/type = “other”, tissue source organ type	Material	string	-	The organ or body part of the biological tissue sample, if not one of listed options.	1	R
	If(Type of sample in individual measurement) = “Biological Tissue”, tissue diseased or normal	Material	string (*)	-	Indicates whether the sample contains normal, diseased or unknown tissues.	1	M
	If(Type of sample in individual measurement) = “Biological Tissue”, tissue source organ/type further information	Material	string	-	This field contains additional information regarding the tissue sample. For example, if the sample is a heterogeneous composition of various tissue types, or if the tissue is diseased what type and grade of disease (if known).	1	O
	If(Type of sample in individual measurement) = “Biological Tissue”, animal information	Material	string	-	Miscellaneous information on the animal, for example age, gender, weight, etc.	1	O
	If(Type of sample in individual measurement) = “Biological Tissue”, tissue state	Material	string (*)	-	The state of the biological tissue sample being measured. The sample may be excised from the animal/patient (ex-vivo), or the measurement may be conducted in-vivo or in-vitro.	1	M

	If(Type of sample in individual measurement)="Biological Tissue"&&tissue state=ex-vivo, time from excision	Material	floating point	h, min, s, less than (min), less than (h), more than (min), more than (h) (*)	If a biological sample is measured ex-vivo, the time since excision. Note that a single value, not a range, should be entered.	1	M
	If(Type of sample in individual measurement) = "Biological Tissue", tissue sample dimensions	Material	floating point	mm x mm x mm cm x cm x cm (*)	If a biological sample is used, this property details the dimensions of the tissue sample.	1	R
	If(Type of sample in individual measurement) = "Biological Tissue", tissue handling procedure	Material	string	-	If a biological tissue is measured, the sample handling may affect the dielectric properties. In this property, the specific handling procedures should be described, for example, including how the tissue was stored, what type of sample container is used, if the sample is moistened or dried prior to measurement, if the tissue was cut into segments, and so forth. Multiple types of handling procedures may be used with a single sample.	m	O
MEASUREMENTS	Number of samples of same type (if measurements not sample-based or site-based)	MUT Recordings	positive Integer	-	This field is only used if the experiment is looking at measurements/data on a tissue or organ-wide basis, without regard to specific sample or specific measurement site on a sample. In this case, this field indicates the number of samples, of the same type, that measurements are conducted on. All tissue samples may be denoted as a single sample type for metadata collection purposes. No site identifiers are then required, as all sites/samples are analyzed as a whole. Within one tissue sample type, only one value for 'number of samples of same type' may be entered. However, an experiment may contain multiple tissue sample types.	1	O

	Number of measurement averages taken over sample (if measurements are sample-based but not site-based)	MUT Recordings	positive integer	-	Multiple measurements may be taken from a sample and then averaged, resulting in a single data file. This may be done with hardware-based averaging or manually, with measurements occurring at one site or multiple sites. This field applies when site-specific information is not available or not of interest, and therefore the samples are being studied as a whole. Each sample has a fixed number of measurement averages. However, an experiment may contain multiple samples, and each may have a different number of measurement averages.	1	R
	Site identifier (if measurements site-based)	MUT Recordings	string	-	Unique identifier for each measurement site on a sample. An experiment may contain multiple samples, each of which may contain multiple sites.	m	M
	Measurement identifier	MUT Recordings	string	-	Unique identifier for each measurement. Each measurement corresponds to a single dielectric property measurement. If site-based measurements, each site may have multiple measurements conducted on it. If sample-based measurements, each sample may have multiple measurements conducted on it (that are not site-specific).	m	M
	Number of measurement averages taken at individual site (if measurements site-based)	MUT Recordings	positive integer	-	Hardware or manual averaging may be used to reduce measurement noise. This property indicates the number of averages taken to make up one single recorded data measurement at a given measurement site.	1	M

	Measurement Timing	MUT Recordings	floating point	h, min, s, less than (min), less than (h), more than (min), more than (h) (*)	The time of the measurement. Each measurement occurs at a single, fixed time. However, multiple measurements may occur, each with a different time point. Note that a single time point, not a range, should be entered.	1	R
	Location of measurement sites on sample [reference to image file]	MUT Recordings	string / image	-	This property describes the location of the sites on a given sample. The sites may be described in text or through photographic images. Multiple descriptions are possible if there are multiple sites.	m	O
	Reference to measured data [location of data file] or the data itself	MUT Recordings	string or array	unitless, S/m, other (if other, enter the unit)	For each measurement instance (i.e., each individual measurement), this is the corresponding measured data. It should be uploaded/stored in array format.	1	R
SAMPLE ANALYSIS	If(Type of sample in individual measurement) = "Biological Tissue", biological tissue processing information	Sample Analysis	string	-	If a biological tissue sample has been measured, the sample may be subject to sample analysis after the measurement is conducted. This property describes any sample analysis that is conducted post-measurement. For example, this may include marking of the measurement location, tissue preservation, embedding in wax, slicing (slice thickness), staining (stain type), histology (method used), imaging, etc. The parameters and details of each type of sample analysis should be provided. A given sample may be subject to multiple types of processing.	m	O
	If(Type of sample in individual measurement) = "Biological Tissue", sample histology	Sample Analysis	string / image file	-	The results of the histological analysis should be uploaded / described here. Multiple types of histological analyses and histological images are possible.	m	O
	If(Type of sample in individual measurement) = "Biological Tissue", sample histology interpretation	Sample Analysis	string	-	The histological interpretation of the site/sample, e.g., "80% healthy gland tissue, 20% malignant", or "normal tissue", etc.	m	O

					Multiple types of interpretations are possible for a given sample.		
DIELECTRIC DATA ANALYSIS	Exclusion criteria for measurement data	Dielectric Data Analysis	string	-	In some cases, exclusion criteria to remove data (likely poor data attributed to errors during measurement, but also due to errors in tissue processing post-measurement that affect interpretation of the data) may be applied. The standard exclusion criteria are based on the Kramers-Kronig relation. The exclusion criteria used to remove recordings should be described here. Multiple exclusion criteria are possible.	m	O
	Dielectric model type	Dielectric Data Analysis	string (*)	-	The type of dielectric model used to model the raw data in closed form. Standardly used models are the Cole-Cole and Debye. For each data measurement, multiple models may be applied.	m	R
	if(Dielectric model type=other), other model type	Dielectric Data Analysis	string	-	The dielectric model type, if not one of listed options.	m	R
	Number of poles	Dielectric Data Analysis	positive integer	-	The number of poles used in the dielectric model. Each dielectric model has a fixed number of poles. However, multiple models may be defined each of which has a different number of poles.	1	R
	if(Dielectric model of individual measurement=Debye), parameter list	Dielectric Data Analysis	array in format [pole number, epsilon_inf ,epsilon_static , tau]	[unitless, unitless, unitless, ps]	The parameters used in the Debye model. The parameters are defined as: epsilon_inf = relative permittivity limit as frequency increases epsilon_static = relative permittivity limit as frequency decreases tau = relaxation time constant Each model fit corresponds to a single parameter list. However, multiple models with multiple parameter lists may be defined.	1	R
	if(Dielectric model of individual measurement=Cole-Cole), parameter list	Dielectric Data Analysis	array in format [pole	can input multiple of: [unitless, unitless	The parameters used in the Cole-Cole model. The parameters are defined as: psilon_inf = relative permittivity limit as frequency increases	1	R

			number, epsilon_inf ,epsilon_static , alpha, tau, sigma_static]	unitless,unitless , ps, S/m]	epsilon_static = relative permittivity limit as frequency decreases tau = relaxation time constant alpha = parameter to broaden dispersion sigma_static = static ionic conductivity Each model fit corresponds to a single parameter list. However, multiple models with multiple parameter lists may be defined.		
	Data to model fit optimization method	Dielectric Data Analysis	string (*)	-	Dielectric data is fitted to dielectric models using fitting algorithms. The fitting technique used is to be noted here. Each data to model fit may involve multiple optimization methods.	m	O
	if(Data to model fit optimisation method=other), other optimisation method	Dielectric Data Analysis	string	-	Dielectric data is fitted to dielectric models using fitting algorithms. If the fitting algorithm is not one of the more commonly used, it should be described here.	m	O
	calculation method for error between data and model	Dielectric Data Analysis	String (*)	-	The method used to calculate the fit error between the data and the model, i.e., how the error or the quality of the fit is determined. For example, average fractional or percent difference over frequency range, chi-squared goodness of fit, etc.	m	R
	Fitting error	Dielectric Data Analysis	Floating point	unitless, S/m, %, other	The calculated fitting error between the model and the data. There may be multiple fitting errors for each data set if different error calculation methods were applied.	m	R