3 Antenna Data Analysis and Processing Tool (ADAPT)

3.1 Assembling of Data in Matlab Structures

Correct parameter extraction requires a profound and accurate handling of measured data. In the RF and Microwave Research Laboratory of the Technische Universität Ilmenau, the measured data is obtained from three different labs, each having different output formats. To ease parameter extraction, it is important to transform all data into a standard format and to arrange them in pre-defined structures. In this thesis Matlab® 2015a version is being used to handle data and for the creation of structures. Figure 3.1 gives a brief overview of the ADAPT.

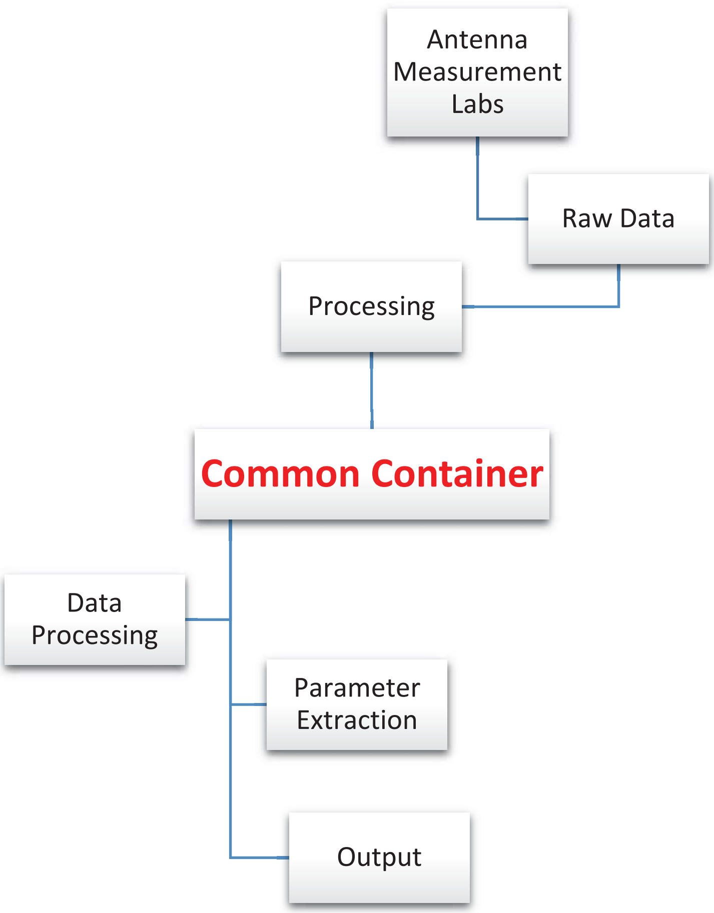

Figure 3.1: Overview of an antenna data analysis and processing tool (ADAPT). RF and Microwave Research Laboratory, Technische Universität Ilmenau.

3.2 Data Processing Stages

The first important stage of parameter extraction is the creation of a .mat file, which is then passed on for the parameter extraction. To create that, the whole process has been divided into two major stages i.e.

1- Pre-processing Stage (Reader)

2- Post-processing Stage (CreateMat)

The requirement of having two stages is motivated by the fact that all labs have a different way of exporting data from the measuring equipment. They not only differ in file formats but also in the structures. The task of the pre-processing stage is first to import the data into Matlab. Once the data is properly imported into the Matlab workspace, manipulation of data begins which starts creating the predefined structures. When the considered data has been passed from the pre-processing stage, it is being forwarded to the post-processing stage. Here additional information is added, and supplementary structures are created. This additional information is required for further interpretation and adjustment of data and where ever required, it is used in the extraction of different parameters.

3.2.1 Pre-Processing Stage

For three different measurement facilities, four different readers have been implemented. Two for antenna measurement lab (AML) lab and one each for VISTA and EMscan RFxpert. Two readers are required for AML lab because it can output data in two different formats i.e. (.NSI and .txt). It is because in the antenna measurement lab (AML) far-field (FF) measurement for electrically small antennas can be directly done. These measurements are output in (.NSI) format. For electrically large antennas spherical near-field (NF) measurements are done and the data obtained is then transformed into the far-field (FF) which is output as a set of multiple (.txt) files or as a single (.NSI) file.

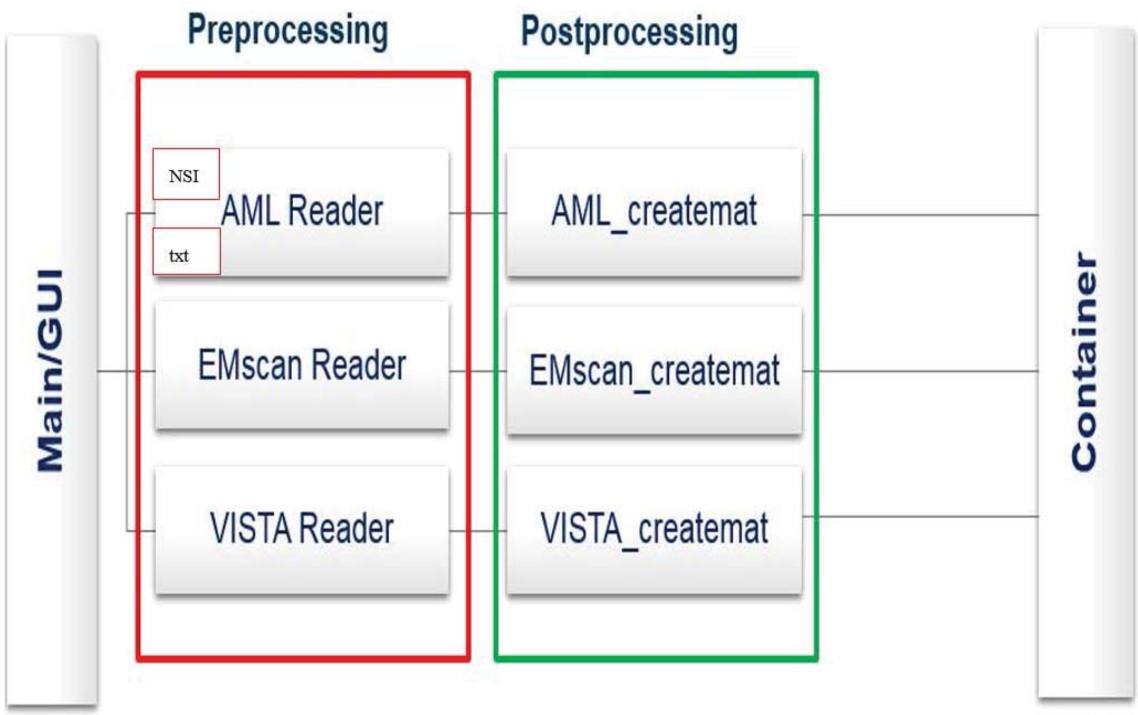

Figure 3.2: Flow diagram of data processing in ADAPT.

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3.2.2 Post-Processing Stage (Creating .mat file)

It is a stage immediately before the creation of a Matlab (.mat) file. It requires multiple input files. The first set of files is the measured data of the AUT. To calibrate the data that is acquired in a far-field AML measurement, calibration data file of the calibration antenna and gain table needs to be inserted. The calibration is done according to the equation (2.16). Beside this, there is a possibility of inserting multiple optional files like image files of the setup and antenna's S-parameter measurement file. Finally after some manual input the **.mat** file is created which is ready to be processed in further analysis and parameter extraction.

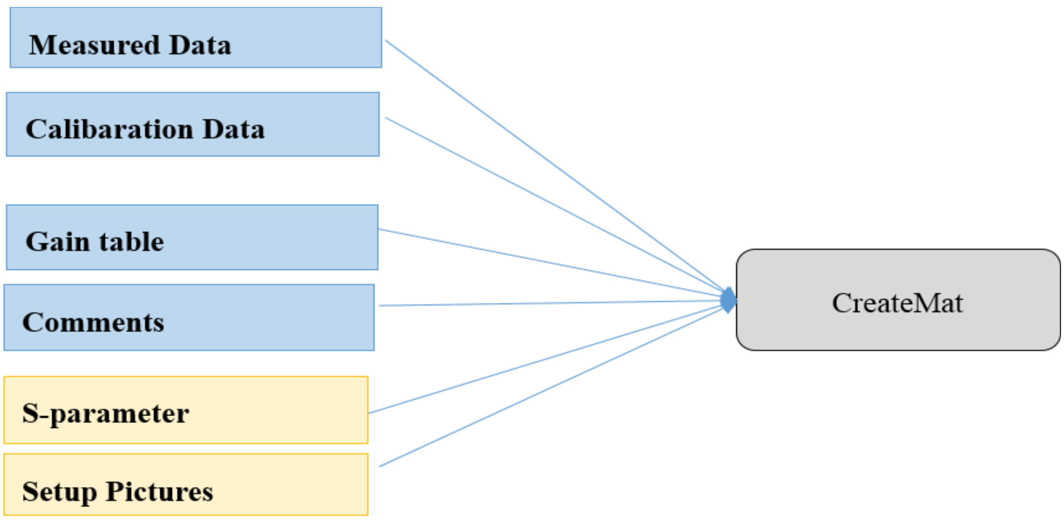

Figure 3.3: Flow diagram of CreateMat procedure in ADAPT.

This procedure explains the required data needed for parameter extraction. Beside this, there is a possibility of an addition of supplementary information.

After passing through the above mentioned two stages antenna data is exported in a common format and structure irrespective of lab from which it was obtained. To make this process and following analysis user friendly and interactive, all these procedures are implemented in a graphical user interface.

3.3 Matlab Structures

The output of a **.mat** file contains five structures, which are same for all the labs. The reference of these structures is taken from the already prevailing standard structures in RF and Microwave Research Laboratory at Technische Universität Ilmenau. The structures are as follows

1- AUT (antenna under test)

2- General

3- Pattern

4- S-parameter

5- Wiring

The first three structures contain all the necessary information and data for parameter extraction. The last two items are optional and kept open for future releases of the presented tool.

3.3.1 AUT

This is the first and foremost structure containing important information regarding manipulation of data according to the corresponding lab. In addition to the designation of the lab (*aut.lab*) it has an option of taking antenna name (*aut.name*) as a reference from the user. The field polarization (*aut.polarization.value*) defines what is the polarization of AUT at $\Phi = 0$ °. Beside these, it also contains information about whether the AUT was mounted at origin on the positioner or not. In case if there is some displacement from origin, the field (*aut.positionoffset*) will contain the newly displaced position of an antenna in Cartesian coordinates. This information will be used to correct phase information which is implemented in antenna translation procedure (2.3.4). These are all necessary specifications which the user is required to enter. Also it has an optional fields (*General.power*) which stores the information about the input power at the terminals of antenna (if available) which can be used for the calculation of the far-field parameter defined in section 2.2.4. Besides this, there is another optional field (*aut.positionimage.imagedata)*, which contain images of the mounted AUT in the moment of measurement. These images can be input using the "*imread*" matlab command during the post-processing stage. For this user will be prompted if any images are required to be inserted. If user enters "yes" then directory navigator will open which will help user to select the desired image.

In all structures the "**field**" describes the particular information associated with the AUT. Most of the fields are further broken down into sub sections for example

1- Item (Name)

2- Value (data section)

3- Unit (describing unit to keep harmony among related data).

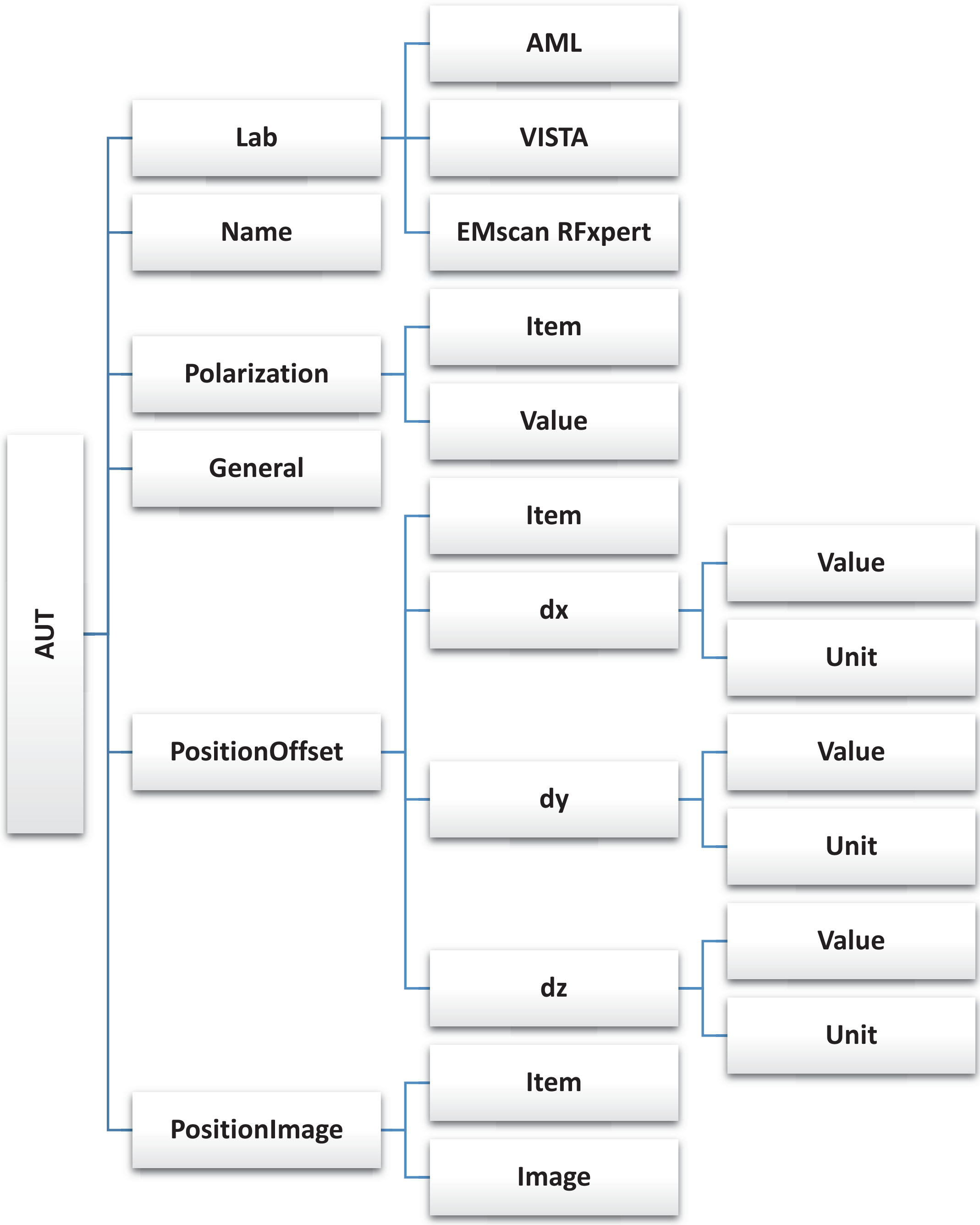

Figure 3.4: Structure of a (.mat) AUT structure of an ADAPT.

3.3.2 General

This structure contains only the general information about the AUT and setup. The first field "**Comment**" asks for any additional comments if user wants to store. Besides this, two other fields i.e. Bandwidth and Source power are also added for the documentation of each measurement.

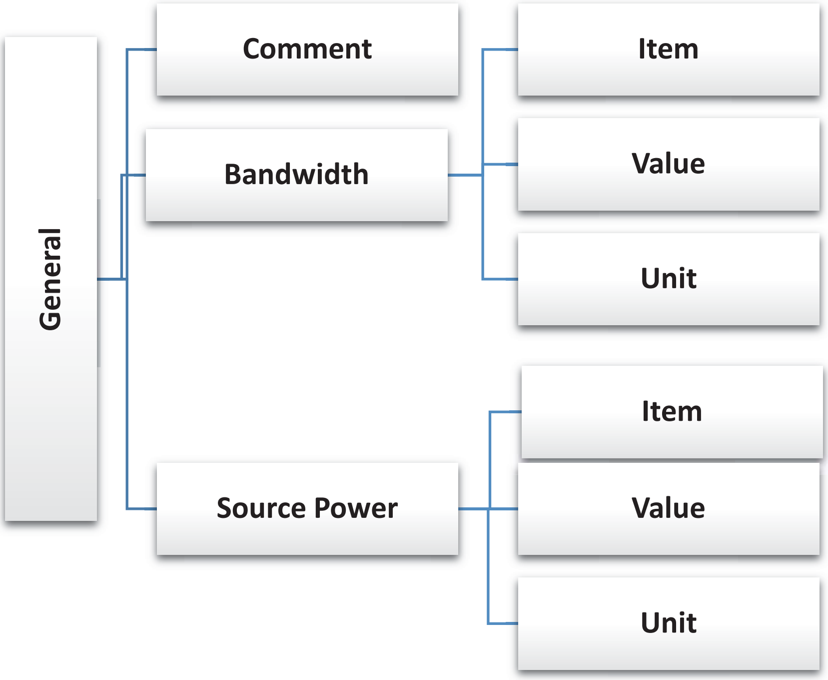

Figure 3.5: Structure of a (.mat) General structure of an ADAPT.

3.3.3 Pattern

This is the foremost important structure of each **.mat** file. Here the actual and later any potentially modified data is stored. All the parameter extraction procedures refer to this structure, therefore careful handling of the data in this structure is required. This is the first structure that is created during data processing (pre-processing stage). Four variables are identified that are necessary for a unique representation of each individual sub-record of a gain pattern measurement for all labs,

- θ (Theta) Elevation of AUT
- Φ (Phi) Azimuth of AUT
- Frequency
- Polarization.

Two important fields of this structure are,

- Value
- Dimension.

Value field contains all the calibrated and uncalibrated data, of each lab respectively in a specific matrix format (two-dimensional where each dimension correspond to either θ or Φ). In all created data matrices, column corresponds to measured θ angle increasing in ascending order and row corresponds to measured Φ angle increasing in ascending order.

Dimension field contains the above presented four variables. All the data in value field is linked to corresponding variable data in dimension field. This linking between data is important because usually measurements are done over certain frequency range and during the parameter extraction process, analysis is done per frequency. That's why correct order needs to be maintained between data in "*Value*" field and variables in "*Dimension*" field. This is taken care of with the help of pre-processing stage where after reading, relevant data and variables are arranged in the ascending order.

Figure 3.6 explains the construction of a pattern structure. The difference in two AML field values can be understood from the fact that AML can output the data in two different formats. Also for AML measurements calibration is done afterwards in the Matlab code, so calibration data also needs to be input by the operator. While in VISTA and EMscan calibration information is directly included in the measurement process of the equipment. All labs use same calibration procedure based on the measurement of the known calibration antenna as explained in section 2.2.3. An important note here is that, difference between two fields i.e. "*Measurement*" and "*Dimension*" is that in "*Dimension*" field modified data scheme is stored which means that the arrangement of data follows the standard form i.e. azimuth or Φ having a span of $0^{\circ} < \Phi < 360^{\circ}$ and elevation or θ having a span of $0^{\circ} < \theta < 180^{\circ}$. While in "*Measurement*" field original measured data scheme is stored. The main idea behind this was for testing purpose and enabling user to use other procedures, besides what's been integrated in this tool for parameter extraction. It will also help user to find out how and in what order data was originally exported from the measuring equipment if user doesn't have original measured data files.

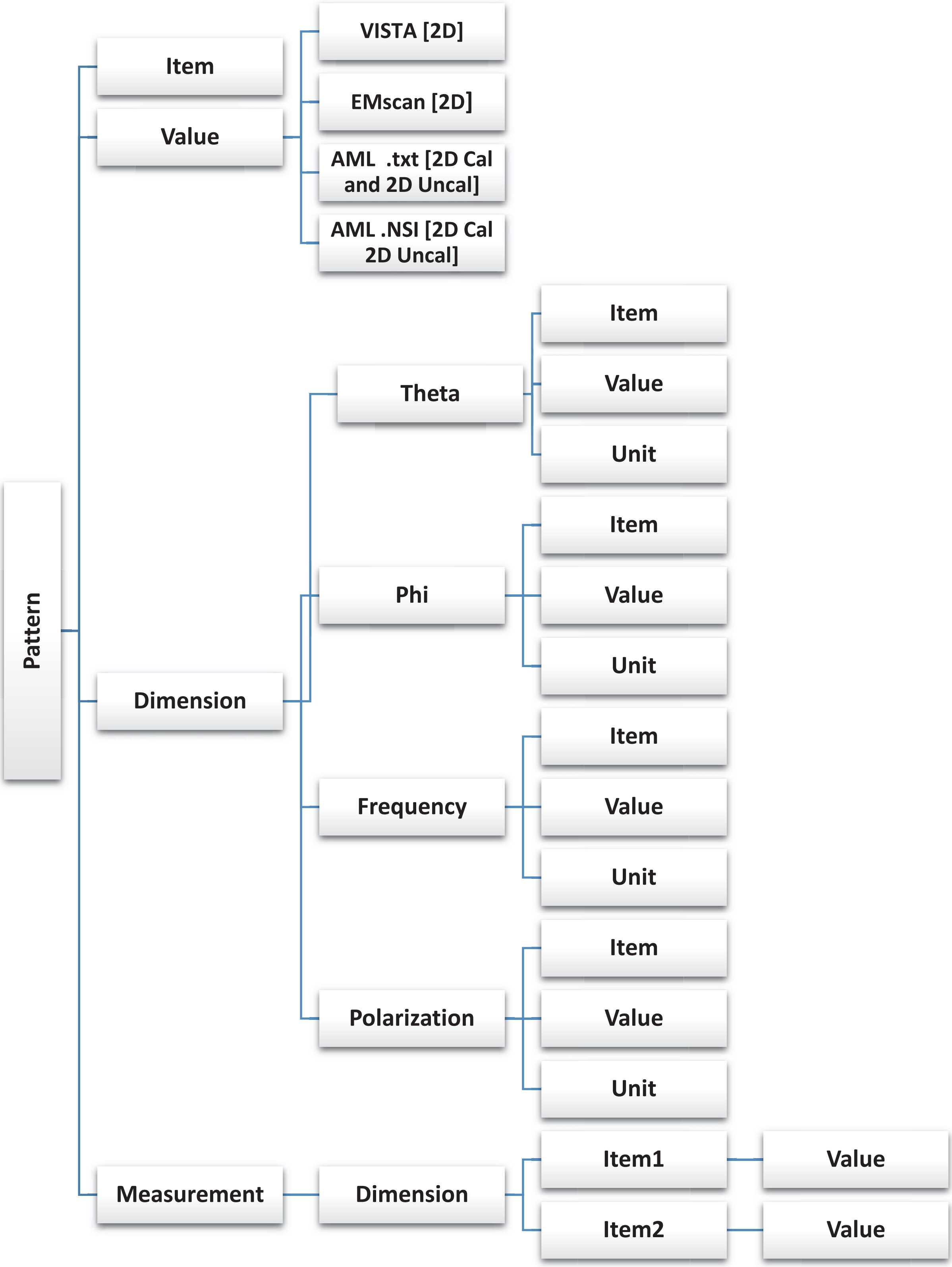

Figure 3.6: Structure of a .mat Pattern structure of an ADAPT.

3.3.4 S-Parameter

This is an optional structure containing the S-parameter data. These measurements are taken with the help of network analyzer, which generates a file in touchstone S2P format. This header is read with the help of built-in Matlab function (*hdrload*) which loads the data and header separately. The header of this ASCII file contains information about the position of the S-parameter data in the file and the frequency. The actual data is stored in the Data field.

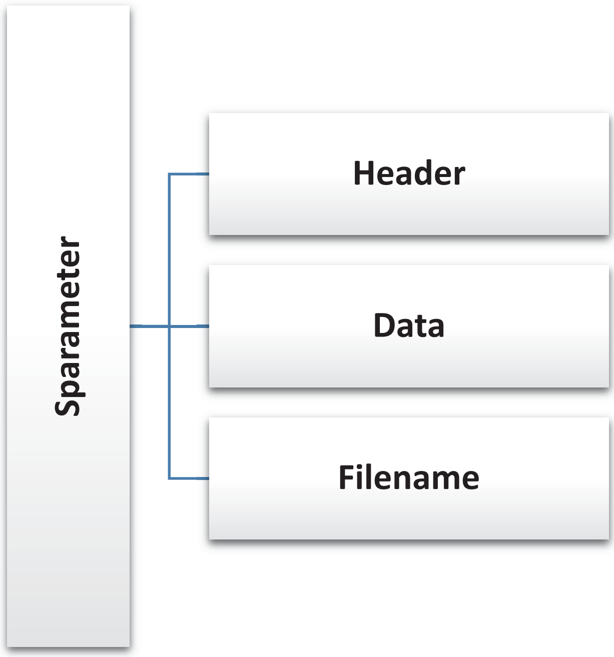

Figure 3.7: Structure of a .mat S-parameter structure of an ADAPT.

3.3.5 Wiring

This is the last and also an optional structure of .mat file which contains the images of wiring being used during measurements. Potential items that may be involved in the measurement are cables, attenuators, mixers, isolators, amplifiers and so on. As all labs deploy different setup procedures to take measurements and these labs also have different frequency ranges, so to see which RF and control wiring has been used during the antenna measurement process, this structure can be loaded with relevant images as shown in Figure 3.9 for future reference and preparation of final analysis document.

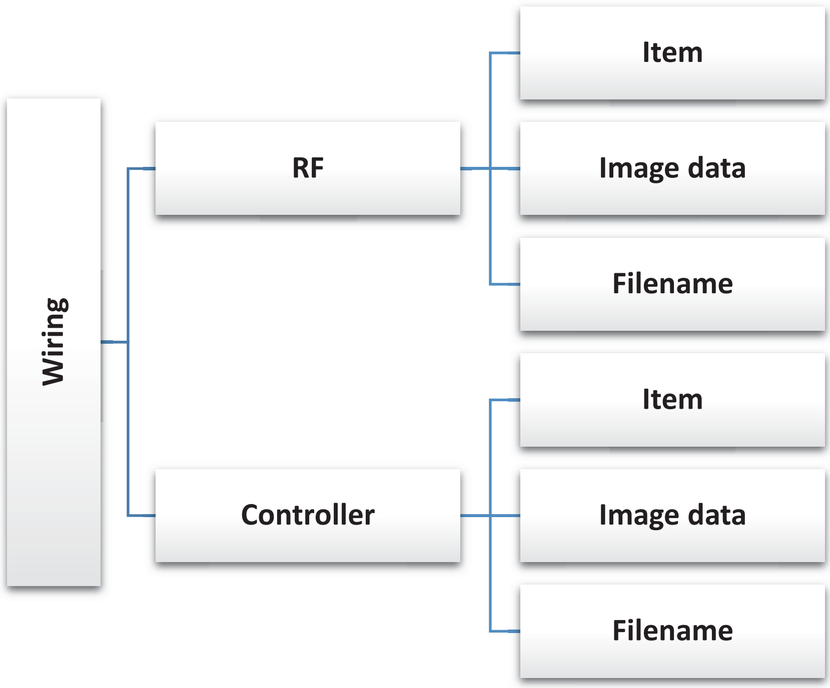

Figure 3.8: Structure of a .mat Wiring structure of an ADAPT.

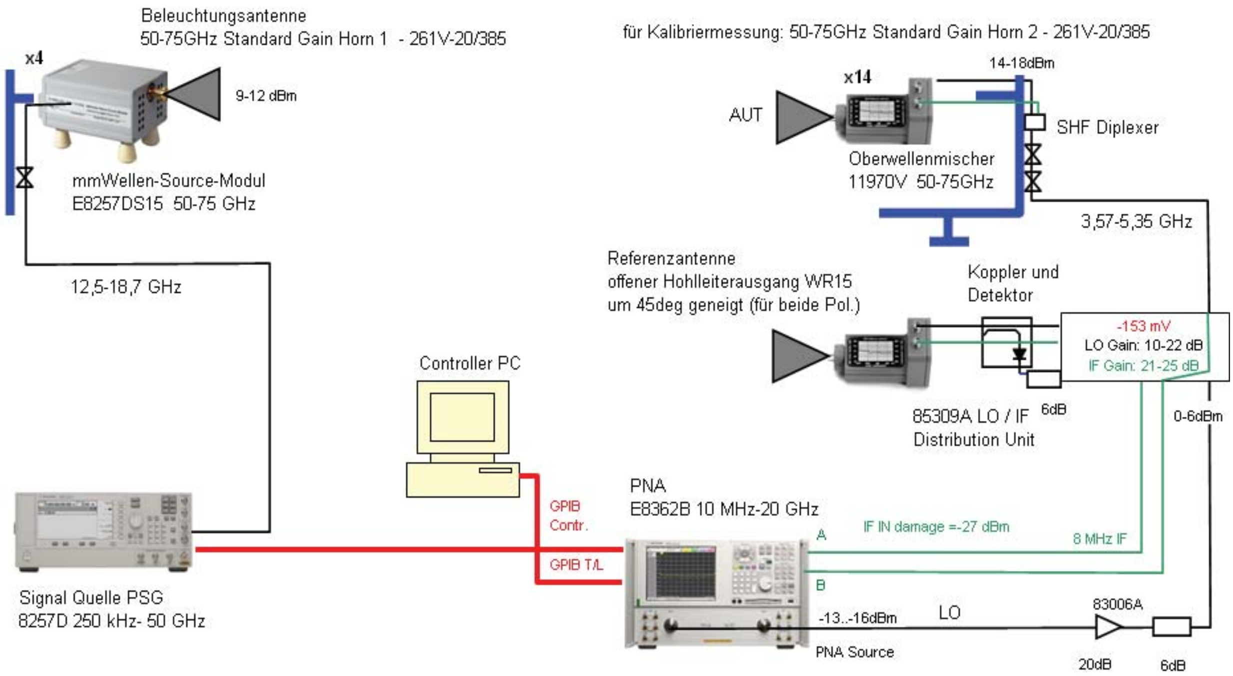

Figure 3.9 Example of attached wiring image used in AML.
Frequency range 50-75 GHz (Photo credit: Mr. Michael Huhn).