Measurement report

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Abstract

This report is based on the paper *First SIMO Harmonic Radar Based on the SFCW Concept and the HR Transfer Function*. The above-mentioned paper presents a new SIMO radar system based on a harmonic radar stepped frequency continuous wave architecture. This set-up can be used as a scanner to identify certain objects by size and type. In addition, chocolate can be tested for purity if impurities have arisen in the manufacturing process, for example chipping from molds. Besides the rudimentary made first measurements published in the mentioned paper, this report concludes the experimental set-up of a much larger measurement routine to provide a big set of data to analyze. The aspirations of the authors are that an enthusiastic group of artificial intelligence (AI) programmers take the data to train their AI to evaluate the position of the material under test by unknown data sets. Therefore, we provide many samples all well categorized with a small set of unknown data to verify the AI feasibility.

Keywords

SIMO — Harmonic Radar — MUT measurement — scanner— non linear — SFCW

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Introduction

A solid understanding of the technology used in this report is a mandatory step before the analyzing can begin. Therefore not only the name of the paper but a link to its download page is provided in the abstract. In addition to this the DOI *10.3390* can be of help to find the paper otherwise. Between a RX/TX antenna and an antenna matrix several differently sized open-end wrenches, material under test (MUT), were placed. The experiment measured the Harmonic Radar (HR) transfer function which magnitude and phase can be used to differentiate between the MUTs.

1. Mechanical measurement set-up

The harmonic radar is connected via coaxial cable with the RX/TX antenna shown in the upper middle of Figure 1. Besides the different polarized antennas, the orange object symbolizes the material under test (MUT), the bigger yellow rectangle beneath is the plastic sledge, made of HDPE, to hover the MUT above the mixed frequency switched reflection matrices (MFSRM) consisting of 15 elements. The enclosing structure is made of aluminum beams from the company *item*. To archive a better understanding of the set-up the Figure 2

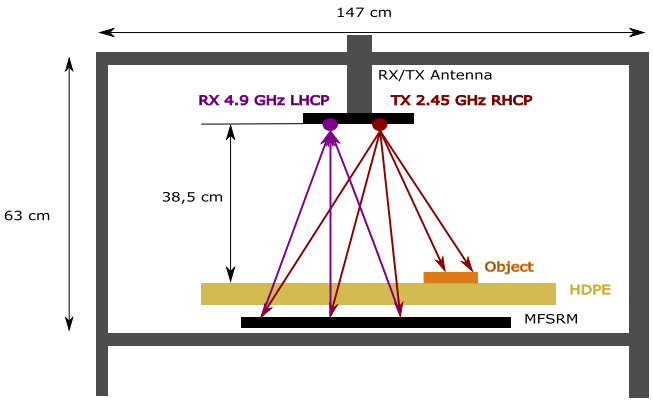

Figure 1. Illustrated cross-section of the measurement set-up

pictures the set-up comprehensively. Utterly important for further comprehension of the orientation of the antenna matrix and alignment of the MUT on it, is the orientation of the antenna matrix relative to the room. Therefore important markers like the door on the left site of the set-up and the wall facing one site of the measurement stand are highlighted in the following picture.

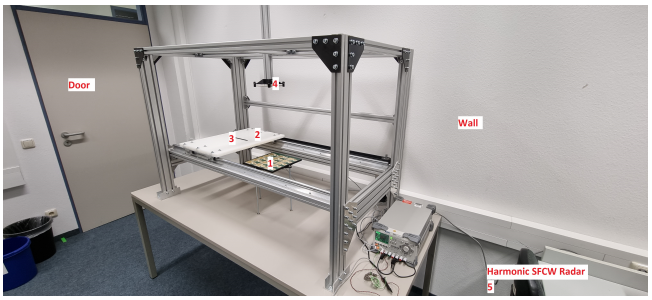

Figure 2. Picture of the measurement set-up

Furthermore a solid documentation is rather important, therefore a camera was positioned next to the RX/TX antenna to additionally take visual hints how the MUT laid on the antenna matrix. Some influence of the camera to the measurement cannot be objected, thus its position is documentated in the following picture.

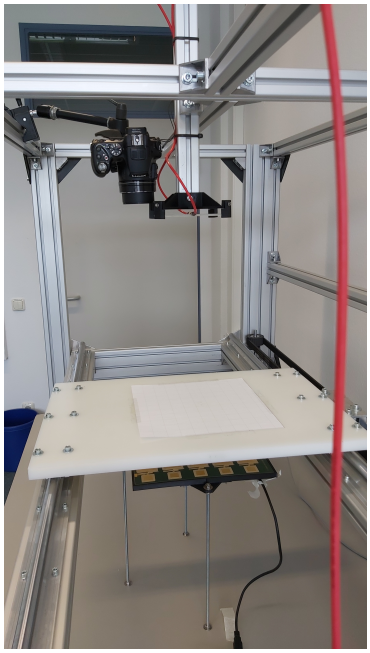

Figure 3. The camera is around ten centimeters away from the center of the RX/TX antenna.

The Figure 2 shows the real measurement stand. In addition to this we added markers to better link the illustration and the real set-up.

Table 1. Table of markers in Figure 2

Number	Name
1	MFSRM
2	HDPE
3	Object/MUT
4	RX/TX antenna
5	SFCW Radar

1.1 Alignment of antenna array in set-up

After a thorough discussion of the way the mechanical set-up is located in the room, the orientation of the antenna matrix within the set-up is relevant to interpret the data correctly.

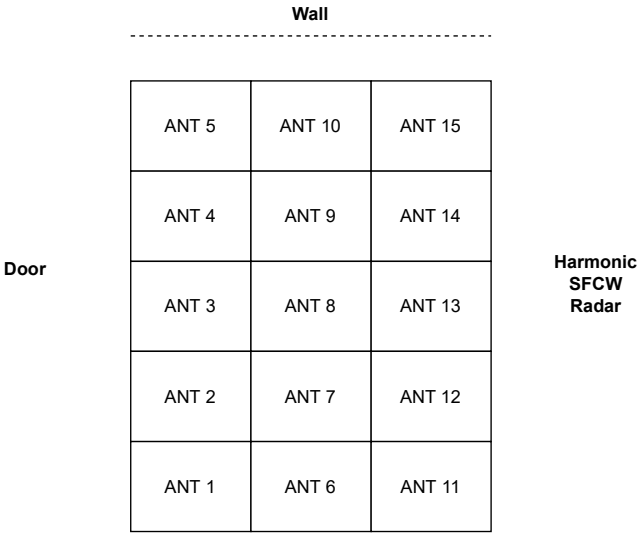

Figure 4. Orientation of the antenna elements in reference to the room.

2. Execution of measurement

Every measurement was taken in a static environment. This means that the HDPE sledge were motionless centered between the MFSRM and the RX/TX antenna. The MUTs were positioned in different orientations on the HDPE sledge, more details on that later. Furthermore, different sized materials were taken, each measured in different orientations on the HDPE. One measurement includes one MUT in a distinct orientation put motionless on the static HDPE and each of the 15 elements of the antenna array measured their own HR transfer function. The data is stored in an excel sheet, more details on that later. The data set includes 50 measurements, each measurement with a picture of the actual object embedded in the set-up to verify the data with an optical counterpart. Two out of the 50 measurements are measurements taken as reference, the remaining 48 are also divided into 43 known measurements and five measurements with unknown object size, orientation and without a picture.

3. Position of MUT

The MUT was once placed horizontally above different sections of the antenna array and in the same manner once placed vertically. The third type of orientation was a counterclockwise rotation around the center of the open-end wrench in the following steps (0, 30, 45, 60, 90,120,150, 180, 210, 250) measured in degree. Although you will see on the pictures an orange paper stripe with the measurement number on it, its purpose is to better visualize which picture belongs to which measurement. However, this paper stripe was taken away every time a measurement took place and therefore has no influence on the data or must be considered.

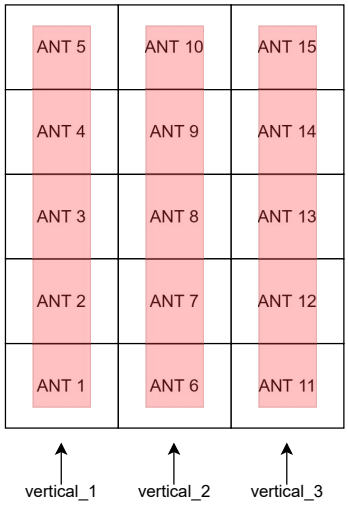

Figure 5. This shows the MUT orientation on the antenna array. The MUT is represented as the red stripe. Considering this type of alignment, we differentiate three types of orientation as the picture illustrates.

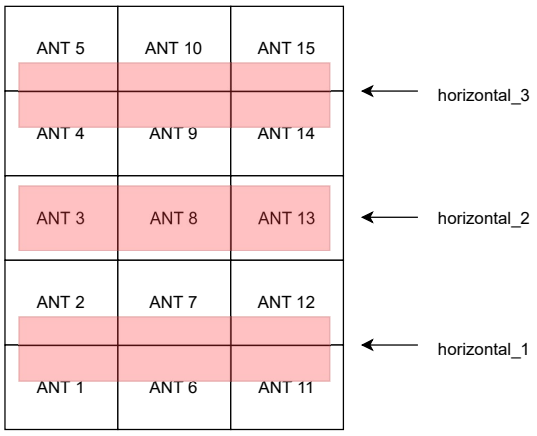

Figure 6. This graphic illustrates the three types of horizontal orientation we chose to make the measurement. The red stripe also symbolizes the MUT position on the antenna array.

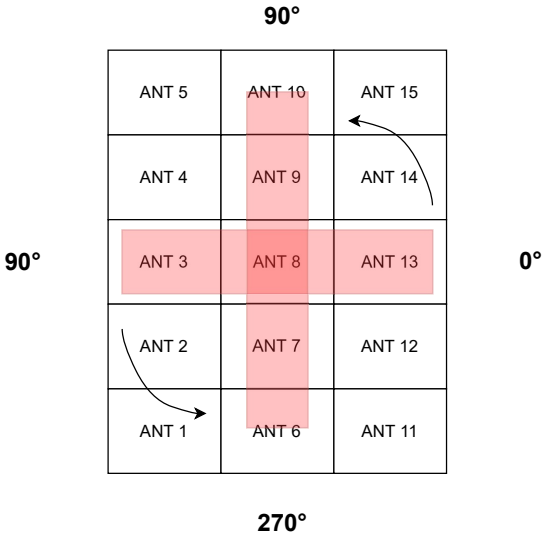

Figure 7. In this picture the third way of placing the MUT on the antenna array is shown. Hereby the MUT does a counterclockwise movement in discrete steps, liked discussed earlier.

4. Format of data

There is one excel file per alignment and size of the open-end wrench. Every excel file has 15 data sheets with data stored for each antenna element. Furthermore, the data is stored in columns like DAC Value1, DAC Value2, Magnitude, Phase and Frequency. The optional data points MaxGainDAC-Value, Max Magnitude and Min Magnitude are probably not of interest for the data evaluation. Most of the information for recognition is stored in the magnitude and phase. These values should be targeted by any enthusiastic AI programmer.

5. Overview measurement routine

Table 2. Table of measurements

No. Image	Object/MUT	Position	Filename
1	open-end wrench 22/20	vertical_1	1804202302
2	open-end wrench 22/20	vertical_2	1804202303
3	open-end wrench 22/20	vertical_3	1804202304
4	open-end wrench 22/20	horizontal_1	1804202305
5	open-end wrench 22/20	horizontal_2	1804202306
6	open-end wrench 22/20	horizontal_3	1804202307
7	open-end wrench 14/15	vertical_1	1804202308
8	open-end wrench 14/15	vertical_2	1804202309
9	open-end wrench 14/15	vertical_3	1804202310
10	open-end wrench 14/15	horizontal_1	1804202311
11	open-end wrench 14/15	horizontal_2	1804202312
12	open-end wrench 14/15	horizontal_3	1804202313
13	open-end wrench 6/7	vertical_1	1804202314
14	open-end wrench 6/7	vertical_2	1804202315
15	open-end wrench 6/7	vertical_3	1804202316
16	open-end wrench 6/7	horizontal_1	1804202317
17	open-end wrench 6/7	horizontal_2	1804202318
18	open-end wrench 6/7	horizontal_3	1804202319
19	open-end wrench 22/20	0 °	1804202320
20	open-end wrench 22/20	30 °	1804202321
21	open-end wrench 22/20	45 °	1804202322
22	open-end wrench 22/20	60 °	1804202323
23	open-end wrench 22/20	90 °	1804202324
24	open-end wrench 22/20	120 °	1804202325
25	open-end wrench 22/20	150 °	1804202326
26	open-end wrench 22/20	180 °	1804202327
27	open-end wrench 22/20	210 °	1804202328
28	open-end wrench 22/20	250 °	1804202329
29	open-end wrench 14/15	0 °	1804202330
30	open-end wrench 14/15	30 °	1804202331
31	open-end wrench 14/15	45 °	1804202332
32	open-end wrench 14/15	60 °	1804202333
33	open-end wrench 14/15	90 °	1804202334
34	open-end wrench 14/15	120 °	1804202335
35	open-end wrench 14/15	150 °	1804202336
36	open-end wrench 14/15	180 °	1804202337
37	open-end wrench 14/15	210 °	1804202338
38	open-end wrench 14/15	250 °	1804202339
39	open-end wrench 6/7	0 °	1804202340
40	open-end wrench 6/7	30 °	1804202341
41	open-end wrench 6/7	45 °	1804202342
42	open-end wrench 6/7	60 °	1804202343
43	open-end wrench 6/7	90 °	1804202344
44			1804202345
45			1804202346
46			1804202347
47			1804202348
48			1804202349
49	with camera		1804202350
50	without camera		1804202351