

Visualisation of EMI in real-time

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Abstract— Standard methods to measure the radiated electromagnetic emissions(EMI) use several measuring positions around the equipment under test(EUT). Most of these standards require the measurements to be done in the Frequency-Domain(FD) which can take several hours. Some emissions could be underestimated because of these methods. The measurement speed can be increased by using the Time-Domain(TD) instead of the Frequency-Domain for the measurements. Another effect of the Time-Domain is that the antenna now has the possibility to move slowly around the equipment under test while measuring. This also means that more points can be measured. Modern technology provides the possibility to track the antenna path during the entire measurement. By using this information an electromagnetic field density map surrounding the equipment under test can be plotted. This paper is proposing a fast measurement method that combines the Time-Domain measurements and antenna position tracking using infrared diodes in order to create an electromagnetic emission map around the equipment under test in Real-Time.

I. INTRODUCTION

The EMI emission of EUT's used to be measured at limited positions around the EUT. This lead to some underestimations of the highest radiated emissions. The standard measurement of radiated EMI was based on the frequency domain(FD) which meant a long measurement time especially in the low frequency range. However even if the traditional FD measurements are accurate the possibility to measure the time-variant is limited, because in this case each frequency step should be measured during a certain time which in turn increases the measurement time even more. Due to the technical progress the measurements can now be done in the time-domain. In the time-domain, all frequency components are measured at once and by using the fast Fourier transform the highest emissions can be detected. This method greatly reduced the measurement time, because the results were immediately available. Due to this opportunity the antenna could be moved continuously around the EUT. Using this opportunity the entire surface can easily be evaluated in a short amount of time, which decreases the chance that the highest radiated emissions are missed.

The chance to miss the highest radiated emissions is reduced even more when antenna tracking is used during the continuous measurement in the time-domain [1]. Since the path of the measurement does not need to be predetermined, points of interest can be measured more extensively. These points of interest can be determined by experience or during the measurement itself. For tracking the antenna there are multiple ways such as object tracking or by using an infrared marker with camera's. With object tracking a kinect camera with tracking function can be used. This tracking function can

be used to track the movement of the antenna and determine the spatial coordinates of the antenna [2]. Another way to use object tracking is in combination with machine learning. The program learns to detect the antenna in the footage of a camera based on pictures of the antenna in different situations. This method can also incorporate the angle of the antenna while measuring and thus give more detail about the measurements. However for high accuracy detection there need to be a large amount of photos in different settings and the camera cannot have objects in sight that are similar to the antenna [3]. The location of the antenna can be determined by using the difference of the marker position detected by the two camera's. Using this method of position tracking the 3D coordinates of the antenna are determined [4].

The information from the antenna tracking can be used in combination with the measured data to create an intensity map of the highest radiated emission around the EUT. Using the intensity map the points of interest can be easily detected. It is also possible to detect area's that have been missed during the measurements. However it would be more practical to know this information about areas with the highest emissions during the measurements. In this case, the chance to skip areas with the highest emissions will be decreased even more.

Making the information visible during the measurements can only be done if every part of the setup measures and processes the data and position of the antenna in real-time. In this paper, the possibility to provide real-time measurements with antenna tracking and post processing of the measured data will be investigated. The antenna tracking will provide 3D coordinates. However in this paper only 2D coordinates will be combined with the measured data from the antenna in order to make an intensity map of the highest radiated emissions around the EUT. The measurements and the tracking together with the visualisation will be done every 0.4 s. This is to make sure that the entire process will be done in real-time. The method used here has greatly reduced the change to miss the highest emission since it is now possible to accurately react to missed areas and points of interest that become visible during the measurements.

II. MEASUREMENT STANDARDS

The standard measurement method for low frequencies are the test method NRE01 [5] or RE101 [6]. These measurement methods use the frequency domain, in which each frequency is measured and analysed separately, with a small bandwidth. In this case, even for one antenna position the measurement time should at least be 1 minute.

For a full analyse of the EUT this measurement needs to be repeated for several dozens of positions. In [1] the measurement parameters for the standard NRE01 were shown.

III. MEASUREMENT SETUP

The setup that will be used during the measurements is based on the time-domain measurement technique described in [7]. For this measurement a 13.3 cm loop antenna was used according to the NRE01 standard for measurements in the frequency range between 30 Hz and 100 kHz. During the measurements the EUT is represented as a cabinet with an arbitrary signal generator inside. To the signal generator another loop antenna is connected which acts as a strong radiating element within the EUT. The signal generator was producing a 50 kHz sine wave in order to imitate the emission source. The equipment used for measuring the radiated emissions can be seen in figure 2. The PicoScope™ 5444MSO is being used to receive and digitize the analogue signal from the antenna. The camera is a PS3 eye camera of which the standard filter is replaced with a filter from a floppy disk. This method allows for the PS3 eye camera to function as an infrared camera. The digital signal processing was performed on a computer. The processing is separated into two programs. The time-domain data was processed using fast Fourier transform (FFT) in MATLAB. The post processing mimics the peak type detector described in [8]. The video data from the PS3 eye camera is processed in opentrack [9]. Opentrack uses the three infrared points to calculate the coordinates of antenna based on the known distance between the infrared diodes. The location is shared with MATLAB so that the location and the measured data can be combined into an intensity map.

IV. ANTENNA TRACKING

The antenna is being tracked by marking the antenna with three infrared diodes. The camera should only see the infrared light that these infrared diodes emit. Otherwise there can be disturbances in the localization of the antenna. For the camera to see the infrared light the existing filter is replaced with an infrared filter. However since other source can also emit faint traces of infrared light the exposure levels of the camera are reduced so other sources are not detected. The location of these three infrared diodes have to follow the pattern shown in figure 3. For the loop antenna that is being used the infrared diodes could easily be attached to match the configuration for the side. This is not a problem since the program uses the initial position as a reference point for the orientation and movement of the antenna.

As can be seen in figure 3 the program uses the distance between the infrared diodes as a reference to determine the distance that the antenna has moved from the reference position. The distance is converted into a scale from -75 until 75 from the reference point in order to make the screen size constant. The distance that the 75 represents can be changed



Figure 1: An example setup for an EUT

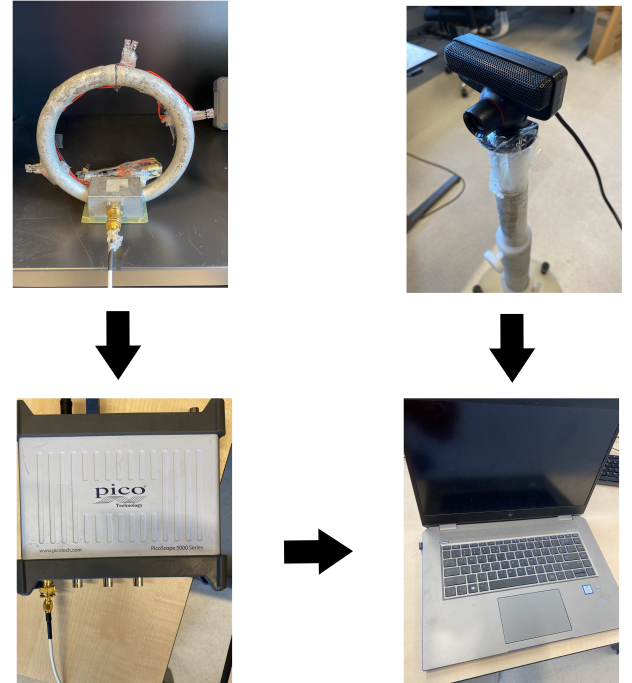


Figure 2: The measurement setup that was used for obtaining the data

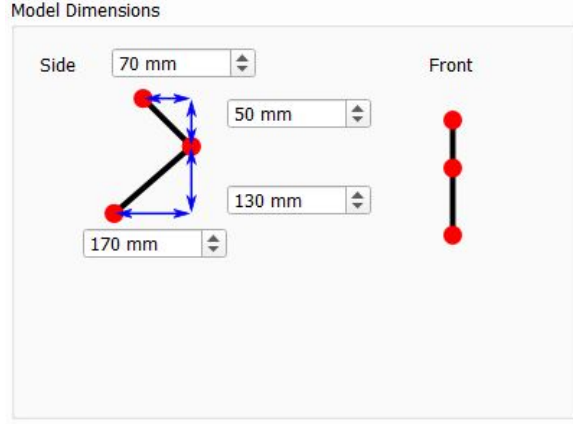


Figure 3: The relative positions of the infrared diodes

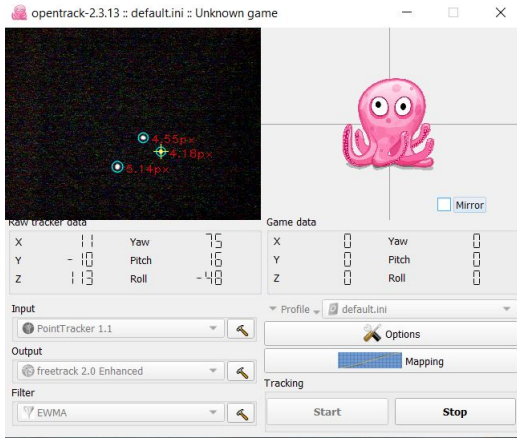


Figure 4: Opentrack tracking the antenna

depending on the size and shape of the EUT. In the top left corner of figure ?? it can be seen how the antenna is being tracked. The camera can only see the infrared light which the diodes emit and uses this information in combination with the reference model from figure 3 to determine the three dimensional coordinates in respect with the reference point. The infrared diodes emit infrared light up to an angle of 60° in order to improve the chances for the camera to detect the infrared diodes while turning or moving.

V. EMI VISUALISATION

Before the intensity map can be made the coordinates found by opentrack need to be communicated to MATLAB. There is not a direct connection between MATLAB and opentrack and therefor opentrack outputs the found relative coordinates into a csv file. From this file MATLAB can read the last entry to match the measured data with. In MATLAB the scale from -75 until 75 is shifted to have only positive numbers and increased so that the intensity map can have more details. The highest radiated emissions need to be stored in a matrix before being able to visualize the EMI. For finding the highest radiated emission the measured value is compared to the value stored into the matrix at the found

coordinates. When the new measured value is higher then the stored value the entry in the matrix will be updated. Since the coordinate does not represent the entire antenna in the matrix an fixed area around the found coordinate is also checked in the same way.

After the measured value has been compared to the stored values the measured area is being found. This is done to minimize the time needed to plot the intensity map and thus decrease the step time of the measurements. The total measured area is found by looking at the minimum and maximum value for each of the coordinates. Some margin is added to these values to give a complete visual representation of the measured area. For the measured area the matrix is being made smooth to make sure that the changes are gradually on the intensity map. Afterwards the matrix is plotted using the surf function to show the intensity map.

VI. EXPERIMENT AND RESULTS

The method described in section IV was used to track the antenna. During the experiments there were different lighting conditions that influenced the accuracy of the tracking. When a bright light source is present in the view of the camera the exposure level of the camera needs to be reduced. This was done so that the tracking program does not mistake these light sources for the infrared diodes. However this also reduces the amount of pixels which make up the infrared diodes. Thus the chance that an infrared diode is too small to be detected is increased. Without only the three infrared diodes the tracking gives either wrong coordinates or the last known coordinate. So for the best tracking results the camera should not face any bright light source such as the sunlight or a lamp. Using this information and the tracking program we can get the results as can be seen in figure 5.

The visualisation was done by using the method from section V. The setup described in III was used for these measurements with the camera one meter away from the EUT. While measuring the antenna started to move according to the uniform method of measuring as described in [1] until an abnormality was detected around the loop antenna. After it was detected the antenna moved around the location of the abnormality to provide more measuring information about the abnormality. In figure 6 it can be seen how the EMI measured around the EUT is visualized. Based on the bright yellow area we can see where the loop antenna is inside the EUT. However during the experiments it was detected that when the laptop was heating up the delay in showing the measured EMI increased. In these cases the antenna had moved on and when MATLAB read the location from the csv file the abnormalities where moved further along the track. This can be prevented by making sure that the computer is not too hot while performing the measurements.

After the intensity map shows areas with increased EMI the standard method can be used that has been described in section II. Using this method it is possible to perform

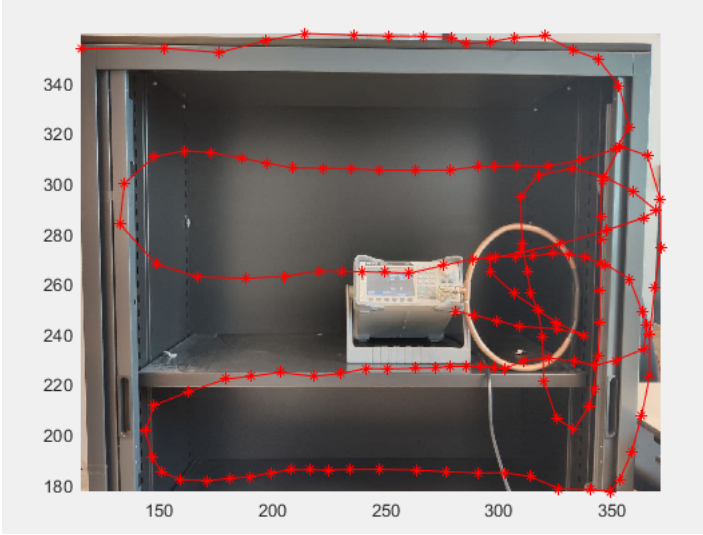


Figure 5: The route followed during the measurements

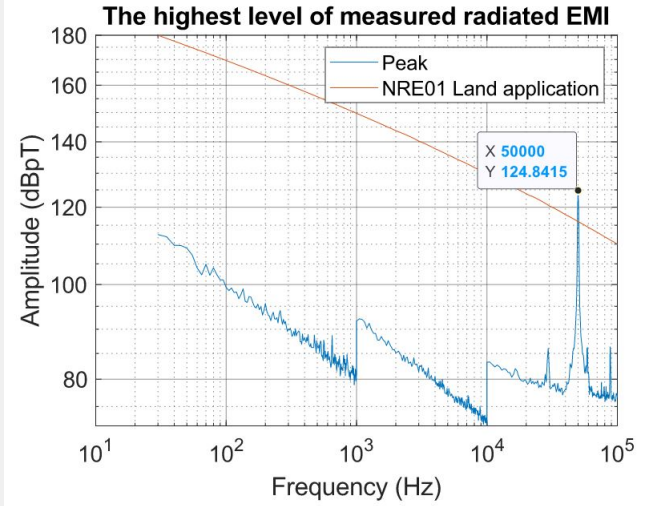


Figure 7: Graph of the highest radiated emission during the measurement

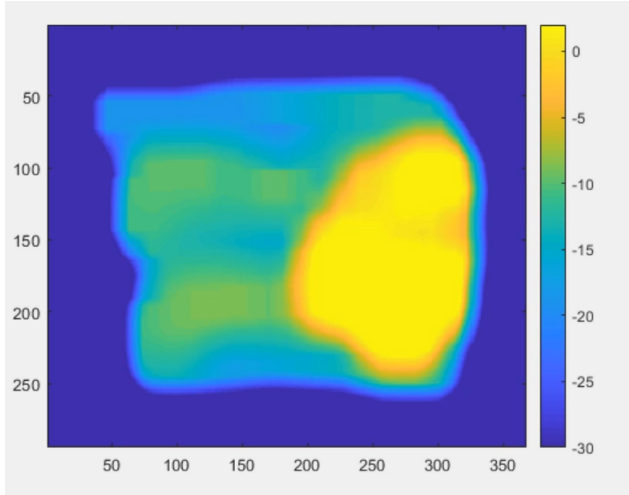


Figure 6: The intensity map of the highest radiated emission around the EUT

a more extensive measurement at that location in order to detect at which frequency the EMI is. In figure 7 the highest radiated emissions for the entire measurement are shown per frequency. In this figure we can see that the peak which crosses the limit line is at 50 kHz which corresponds with the signal that the wave generator is producing.

During the measurements the difference between the steps was 0.4 seconds of which the first 0.2 seconds was for measuring the EMI and the second 0.2 seconds for post processing and visualisation. The best way to reduce the step time is to use multiple cores and do the post processing while the next set of data samples is being collected. MATLAB gives problems when using multiple cores at once and thus a different program should be used. However that is beyond the scope of this research.

VII. CONCLUSION

This paper has shown a method to track the antenna during the measurements and combine it with the measured EMI to create an electromagnetic emission map. The data collection, tracking and visualization can be done during the measurements in order to provide information about the EMI around the EUT in Real-Time. This information can then be used to make Real-Time decisions about the measurement time for each area around the EUT. The method described also reduces the chance that emissions are underestimated since the entire EUT can be measured in a relatively short amount of time.

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