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Improvement of Antenna Measurement Results at Low Frequencies by Using Post-processing Techniques

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Abstract— This paper presents a part of a whole study dedicated to the design of an indoor near-field antenna measurement system in VHF range. During this study a new wide band probe covering the 50 to 400 MHz bandwidth was developed, manufactured and characterized. The paper will focus on the use of post-processing techniques to improve measurement results. Measurements have been done in two different systems. Results are given to show the capability of Time Domain filtering and Equivalent Current Approach to reduce ripples due to reflections and truncation effect.

Index Terms—antenna measurement, low frequencies, VHF, post-processing techniques.

I. INTRODUCTION

Recent enhancements in military telecommunication systems for monitoring and tracking in low VHF range (30-80 MHz) imply the use of specific antenna measurement facilities to characterize either the antenna alone or the antenna mounted on a supporting structure which can be heavy and bulky. Conventional outdoor far-field antenna measurement ranges used at UHF frequency bands and above become poorly effective down in VHF frequency band due to ground effects and electromagnetic pollution. Other implementations such as indoor far-field or compact range are not suitable at these very large wavelengths. A brief state of the art of existing VHF measurement facilities has been done in [1]. The indoor Near-Field approach shows benefits in terms of compactness. However this approach involves issues due to high levels of reflectivity of the anechoic chamber, the Antenna Under Test (AUT) positioner and the measurement probe structure at these frequencies. Studies and characterizations of each component effect have been performed in a previous paper [2].

The proposed paper focuses on measurement results improvements of a new VHF probe using post processing techniques. First is briefly presented the new 50-400 MHz dual polarized probe. Then the two different measurement systems used are described. Post-processing techniques are then discussed and chosen to answer to inherent measurement system issues. Finally results are given to show the capability of Time Domain filtering and Equivalent

Current Approach to reduce ripples due to reflections and truncation effect.

II. SATIMO VHF WIDE BAND PROBE

A new wide band and dual polarized VHF probe has been designed and manufactured. Mass and mechanical stability were critical points for this voluminous antenna as shown in Figure 1 with a weight around 70 kg and dimensions of 2 x 2 x 1.7 m. A mechanical analysis has been performed and the chosen main constituting material is the Metawell [3]. Return losses for each polarization are below -10 dB as shown in Figure 1. Isolations between polarizations are better than 20 dB over the 50 to 400 MHz bandwidth.

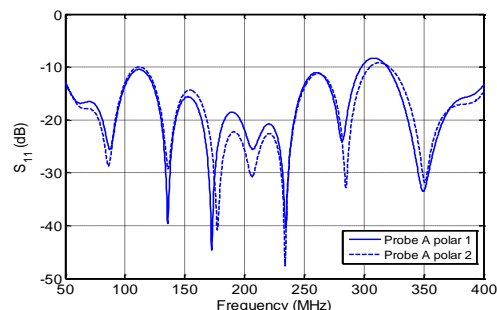
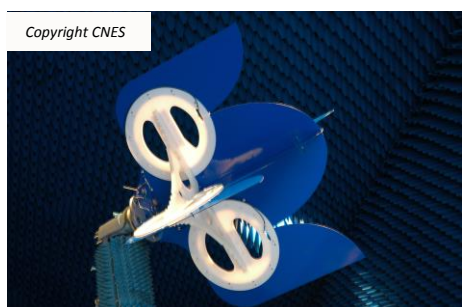


Figure 1 Photograph of the 50-400 MHz dual polarized probe and measured return losses versus frequency

III. MEASUREMENT SYSTEMS

A. CNES Toulouse France

The first measurement facility used is the single probe spherical near field measurement system located in the chamber of the CNES in Toulouse France. This facility is dedicated to perform antenna measurement from 80 MHz to 200 GHz [4]. The chamber is shared by a compact range measurement system and a single probe near-field system. Above 400 MHz the compact range configuration is used. Below 400 MHz the near-field configuration is used. Nevertheless classical foam pyramidal absorbers are poorly efficient below 200 MHz. Therefore ripples due to reflections coming from the compact range reflector and from the chamber walls were expected.



Figure 2 Photograph of the Near Field measurement configuration inside the CNES Compact Range

B. Renault Aubevoye France

The second system used is the multi-probe hemi-spherical near-field range located at the Renault Center in Aubevoye France [4]. The bandwidth of operation is from 70 MHz to 6 GHz. In this second case the very large absorbers present a better absorption than the CNES chamber ones being acceptable from 125 MHz. Moreover no reflecting plane is present therefore less ripples due to reflections were expected. However the main error in this system comes from the measurement surface which is truncated at 102 degrees in elevation. Then ripples due to this truncated surface were expected.

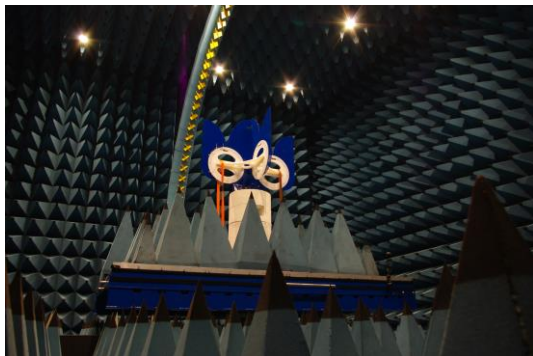


Figure 3 Photograph of the Renault Range

IV. POST-PROCESSING TECHNIQUES

As commented before, because the antenna is measured at very low frequencies, one important error contribution are the reflections coming from the surrounding walls which are covered with absorbers but which are not able to effectively remove them due to their poor reflectivity behavior at these frequencies. The number of approaches to analyze and cancel the effects of these unwanted contributions has increased in recent years. There are methods that are employed not to remove the reflection waves, but rather to characterize the chambers by a figure of merit, usually called the reflectivity level [5]-[7]. Other solutions within the category of so-called compensation methods can be applied to avoid measuring the antenna under test several times at different distances with respect to the probe. Test zone field compensation [8] is one of these methods, and it is used to reduce the effects of undesired fields created by reflections, employing only the data from one measurement performed over a spherical surface. The main drawback of this last technique is the computational complexity, which can be reduced as shown in [9], in which the unwanted reflected components are associated with plane waves with which the error patterns are estimated. Other possible approaches include frequency decomposition techniques, where the signal measured in the frequency-domain is divided into a set of propagating components, including the direct and all the reflected contributions. Next, taking only the desired component, a result quite similar to the one obtained in a fully anechoic chamber may be achieved. The most popular techniques to carry out such decomposition use Prony's algorithm [10], pencil-of-function method [11] or matrix pencil method [12]. Another solution is to perform the measurement with the antenna shifted from the origin and then to apply a modal filtering [13]. In this last technique, the antenna must be located several wavelengths far away from the origin, therefore, in our particular case where low frequencies are use, it is not possible to apply this technique. Other last group of techniques is based on diagnostic techniques with which the field is reconstructed on a surface close to the antenna [14]-[15]. In this domain, if the desired contributions coming from the antenna and the undesired contributions coming from reflections are not spatially coincident a spatial filtering can be applied to suppress the second ones. In the case of a single probe system where the reflection contribution is variable relative to the antenna under test, this approach is less suitable.

The second error contribution is linked to the fact that in the Renault system the measurement is not performed over a surface which fully enclosed the antenna. As a consequence, the true far-field pattern cannot be determined in the whole sphere and is only valid within the so-called reliable region. A second effect, which is caused by the discontinuity of the measured field at the edge of the scan surface, is the presence of a ripple even within the reliable region. There are different approaches which attempt to reduce the mentioned ripple by the application of proper window functions to the near-field data [16]. Another ripple reduction approach is proposed in [17]-[18] in which raised cosine amplitude and quadratic phase

windows are shown to provide high accuracy. Although windowing techniques can greatly reduce erroneous ripples, an extra scan area is needed to obtain the same reliable region. If the scan area is not extended with the use of one of these techniques, the extent of the reliable region is reduced. There is a second group of approaches which do not attempt to reduce the ripple within the region in which the far-field pattern is reliable, but they attempt to obtain a good estimation of the true pattern outside of that region. Another strategy to reduce truncation errors is to rotate the AUT about one or more axes [19], measuring in different planes and combining them to increase the maximum validity angle. Logically, this technique requires a particular near-field to far-field transformation for each combination of plane acquisitions. In [20], the problem of truncation is addressed using *a priori* information about the AUT. The main idea of this approach is to estimate the near-field data outside of the scanning area by extrapolating the measured data before calculating the far-field pattern. The *a priori* information is employed to obtain a non-redundant and non-uniform representation [21] of the samples that are taken over the measurement surface. A new method that is based on the same principle, i.e., the use of a non-redundant sampling in the acquisition, was proposed in [22]. In this method, the truncation error is practically eliminated by also addressing points in surfaces external to the actual scanning area. Therefore, this method can be applied whenever the set-up allows the variation of the distance between the AUT and the probe. Recent publications also use *a priori* information about the AUT in an iterative algorithm to extrapolate the reliable portion of the calculated far-field pattern. This method was proposed for the planar near-field case in [23] and generalized for the most common measurement systems in [24].

In our particular case, a time domain filtering technique and an equivalent current approach are employed to suppress reflections and truncation errors, respectively. More information about these two techniques is given in the two following sub-sections.

A. EQC approach

Equivalent Current Approach (EQC) also called Integral Equation Approach [25] is performed by using the Insight software developed by Satimo [26].

Based on the acquired NF data, Insight computes the equivalent electric and magnetic currents on an arbitrary shaped reconstruction surface conformal to the test object. From the equivalent currents the field on the full measured surface can be evaluated. This process mitigates the pattern error due to scan truncation that otherwise would show as a ripple due to the zero padding of the NF data in the traditional NF-FF transformation [27].

The equivalent electric and magnetic currents computed by Insight on an equivalent surface conformal to the shape of the VHF probe are shown in Figure 4.

It should be noted that the equivalent reconstruction surface also acts as spatial filter [15], mitigating the unwanted effect of echoes or stray signals.

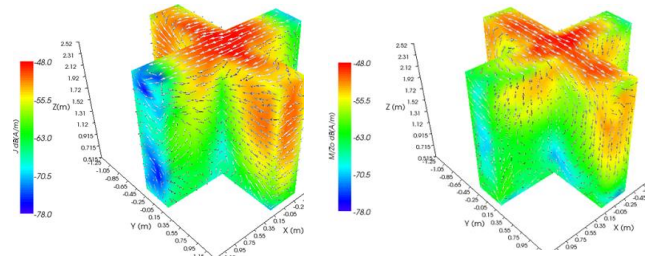


Figure 4 Examples of equivalent current sources for Renault (left: J currents, right: M currents)

B. Time domain filtering

Time domain filtering techniques or time-gating techniques are well-known approaches which can be employed as an option to remove reflected contributions. The main idea is to separate the direct signal from the reflections using a time-domain representation. In the initial approaches [28], [29], the measurement is directly performed in the time-domain by utilizing pulse generators and sampling oscilloscopes. After that, a time filtering and a time-to-frequency transformation are required to infer a reliable frequency response. However, the complexity of the pieces of equipment is lower when using frequency-domain measurements as proposed in [30], which is the technique used in our particular case to remove the effect of unwanted reflections as much as possible. Firstly, the measurement is performed over a wide enough frequency range. Using these data, the time response is immediately calculated by applying an inverse Fourier transform. If there are contributions coming from different places in the measurement set-up (different distances and therefore different times of arrival), it is very simple to identify them in this new domain. After that, direct contribution is detected and gated, eliminating the delayed response due to the reflected and diffracted components. Finally, a Fourier transform is applied to return to the frequency-domain.

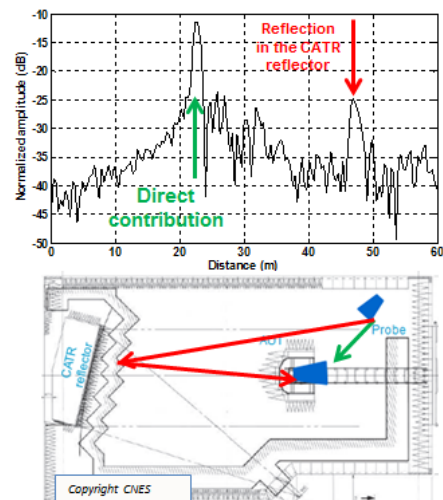


Figure 5 Example of time response in CNES chamber

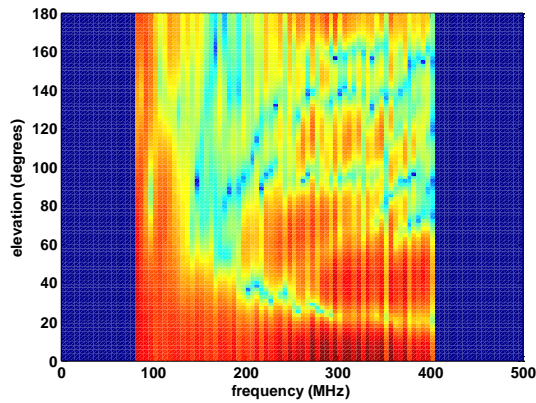


Figure 6 Example of radiated field **before** time filtering for one given azimuth - elevation versus frequency

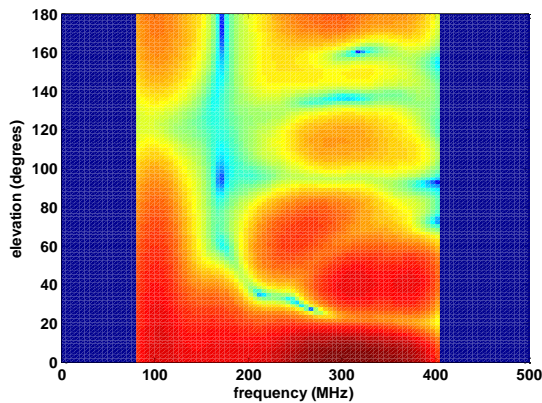


Figure 7 Example of radiated field **after** time filtering for one given azimuth - elevation versus frequency

Figure 5 shows the time domain response for one given direction. Direct and reflected contribution can easily be distinguished. The reflection coming from the CATR reflector is clearly identified regarding the time / distance occurrences. Figure 6 and Figure 7 present the frequency response before and after time filtering respectively for one given azimuth. Strong reduction of ripples can be observed.

V. RESULTS

The time filtering approach is applied in the results obtained in both measurement systems (CNES and Renault) to reduce reflections. However the EQC approach is only applied in the Renault measurement results for truncation matter.

Results examples at 100 MHz of the post-processing are shown in Figure 8 (c) for the time filtering (TF) at CNES and in Figure 8 (e) for both time and EQC post-processing at Renault. The reference simulated result in shown Figure 8 (a). We observe good improvements of the results as shown in Figure 9 and Figure 10 for E plane at 100 MHz and 200 MHz respectively. More results at lower frequencies will be presented at the EuCAP Conference. Uncertainties estimation

regarding these two measurement systems have now to be dressed when using these post-processing techniques.

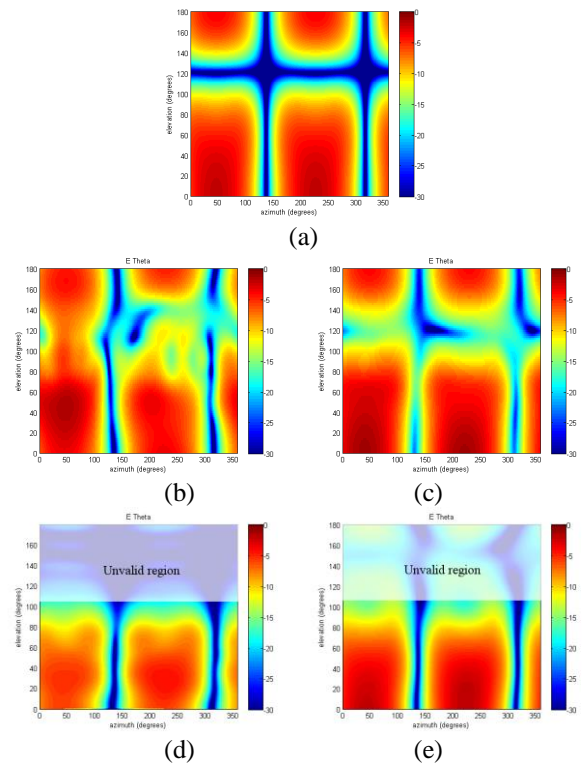


Figure 8 Examples of results at 100 MHz
Theta component - Elevation vs. azimuth plots
(a) Simulation (b) CNES not filtered (c) CNES after time filtering
(d) Renault not filtered (e) Renault after time and Insight processing

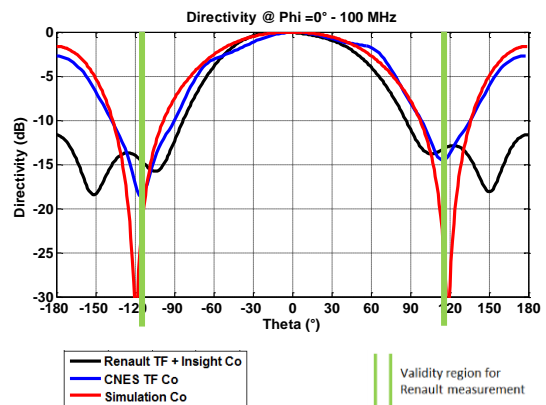


Figure 9 Comparison of radiation pattern cuts @ 100MHz (co-polarization)
- E plane after processing - simulation, Renault and CNES measurement

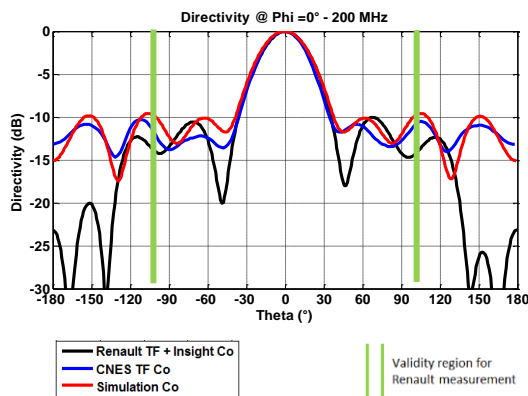


Figure 10 Comparison of radiation pattern cuts @ 200MHz (co-polarization) – E plane after processing – simulation, Renault and CNES measurement

VI. CONCLUSION

This paper presents the use of post-processing techniques to improve antenna measurement results at low frequency in two different measurement systems. Due to the large wavelengths considered measurement results are strongly impacted by reflections coming from chamber walls and system components. Time filtering is better suited compared to modal or spatial filtering at these low frequencies. To reduce truncation effect in the Renault system, equivalent current approach is added. Obtained results are conclusive and underline the capability of indoor measurement systems to measure antenna at frequencies below their specifications.

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