

A Calibration Method Using Interpolation to Reduce Measurement Errors in Electromagnetic Compatibility Measurements

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Abstract—MIL STD 461 is the Department of Defense standard that states the requirements for the control of electromagnetic interference (EMI) in subsystems and equipment used by the armed forces. The standard requires users to measure the unintentional radiated emissions from equipment by placing a measuring antenna at one meter distance from the equipment under test (EUT). The performance of the antenna at 1m distance must be known for the antenna to measure objects located at this close proximity. MIL STD 461 requires the antennas to be calibrated at 1 m distance using the Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 958. This SAE ARP 958 document describes a standard calibration method where two identical antennas are used at 1m distance to obtain the gain at 1m for each antenna. In this paper the authors show using simulations that the SAE ARP 958 approach introduces errors as high as 2 dB to the measured gain and AF. To eliminate this problem the authors introduce a new method for calibrating EMC antennas for MIL STD 461. The Method is based on the well-known extrapolation range technique. The process is to obtain the polynomial curve that is used to get the far field gain in the extrapolation gain procedure, and to perform an interpolation to get the gain at 1 m. The results show that some data in the far field must be collected during the extrapolation scan. When the polynomial is calculated the antenna performance values at shorter distances will be free of near field coupling. Measured results for a typical antenna required for emissions testing per the MIL STD 461 match well with the numerical results for the computed gain at 1 m distance. Future work is required to study the use of this technique for other short test distances used in other electromagnetic compatibility standards, such as the 3 m test distance used by the CISPR 16 standard.

I. INTRODUCTION

In EMC applications it is very common to use antennas in the near field region. Mil Std 461F [1] and its previous versions locate the antenna at 1 meter from the equipment under test. Hence the user needs to know the characteristics of the antenna at 1 m distance. The standard calls for the calibrations to be performed using the technique described in another standard document. The calibration procedure is found in SAE ARP 958 [2]. Per this standard the gain and antenna factor (AF) are measured by locating two similar antennas at a distance of 1m from each other. The measured results are affected by the secondary antenna that is present to measure the gain. the

values affected by the near field coupling between the antennas can give raise to errors on gain of close to 2dBs. The extrapolation range technique was introduced by Newell et al. in the early 1970s [3,4]. In this paper the term extrapolation range will refer to the measurement technique and the location of the measurements. In the extrapolation range technique the S21 between two antennas is measured versus frequency and versus distance. The antennas are moved progressively further away from each other up to a maximum distance. This maximum distance is not necessarily on the far field of the two antennas, but from the measured data the far field behavior can be extrapolated.

In this paper the approach to measure gain introduced in [5] is used to show the error in gain and the potential error in emissions from using the gain obtained from the technique described in [2].

II. RESULTS FOR A DUAL RIDGE HORN

In reference [5] a 200MHz to 2GHz dual ridge horn was studied. This is the recommended antenna for both emissions and susceptibility mandated by the MIL STD 461 [1] for the 200MHz to 1GHz range. Figure 1 shows the far field distance for this antenna geometry.

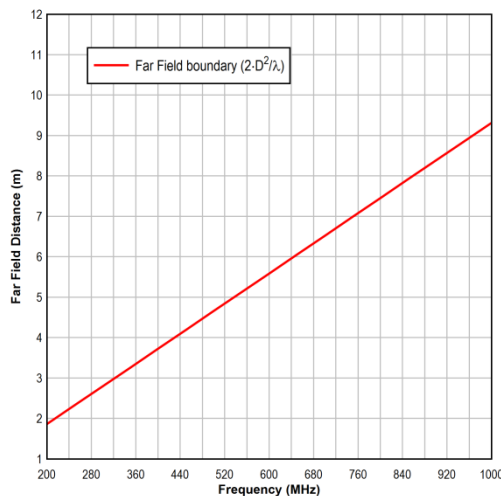


Figure 1. Far field distance for the antenna.

The measured data was collected in an extrapolation range with a maximum of 10m of range. As reported in [5] the extrapolation range data was used to get a polynomial fit for the gain that is then used to obtain the gain at shorter distances. Figure 2 shows the computed field around the antenna. The presence of the second antenna during calibration changes the field around the antenna.

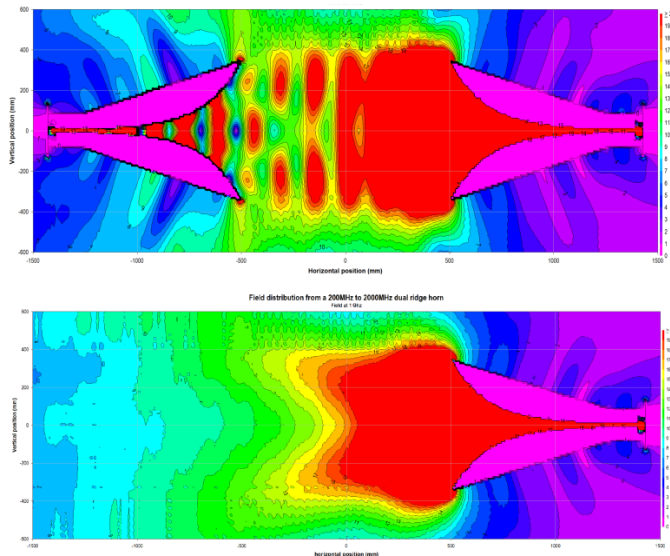


Figure 2. the field distribution at 1GHz for the dual ridge horns during calibration per SAE ARP 958 and by itself.

The field change due to the proximity of the secondary antenna during the calibration affects the gain measurement. During use the second antenna is not present. The field is different and so is the actual gain.

Figure 3 shows the results for the two measurements and the computed gain using the field generated at 1m. The computation was performed using CST MW Studio. The simulation used to generate the bottom portion of figure 2 was used to obtain the field (total field) at one meter from the aperture of the antenna. After sampling the field at 1m distance from the aperture and using simulated input power at the excitation port the following equation can be used to obtain the antenna gain at 1m [5].

$$g(dB) = 10 \cdot \log_{10} \left(\frac{(r \cdot E)^2}{30 \cdot P} \right) \quad (1)$$

Where P is the input power in watts, and r is the distance in meters. E is the field at the distance r in V/m. In reference [5] the authors looked at the gain difference. In figure 3 the results are plotted as antenna factor.

The gain can be converted to antenna factor (AF). The AF relates the field sensed by the antenna to the voltage at the input port of the antenna. Since the AF is the electric field $E(v/m)$ divided by the voltage at the antenna port $V(v)$, its units are $1/m$ or m^{-1} . The AF is a very common parameter in electromagnetic compatibility measurements. For a system with components having a characteristic impedance of 50Ω the gain in dB relates to the AF in dB as follows

$$AF(dB_{m^{-1}}) = 20 \cdot \log_{10}(f(MHz)) - g(dB) - 29.79 \quad (2)$$

Where f is the frequency in MHz. Since the AF is $E(v/m)/V(v)$, its units are m^{-1} .

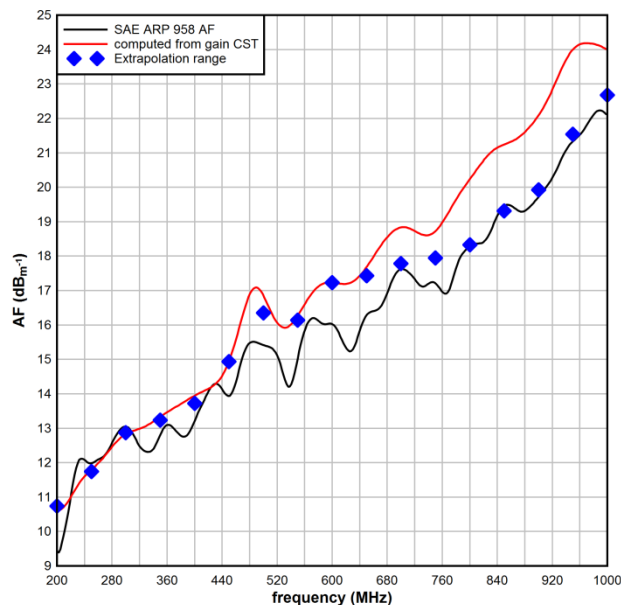


Figure 3. AF versus frequency for the two measurement methods and the computed gain from CST using the field sampled at 1 m.

III. POTENTIAL ERRORS FROM CALIBRATION

Figure 3 shows that all methods follow the same trend. However, as mentioned in [5] the SAE ARP 958 method provides a curve with more ripple. At some frequencies the difference between the SAE ARP 958 AF and the computed AF is almost 2 dB. Figure 4 shows the limits for non-intentional radiated noise from subsystems and components per MIL STD 461 F [1]. The limits vary depending on the branch of the service and the intended environment where the system will operate. For example, at 600MHz the component or subsystem cannot radiate over $39.5dB_{\mu V/m}$ if it is intended to be used by the Army on the ground or external in an aircraft or outside the pressure hull of a submarine for the Navy. Let's assume that an EUT being tested shows a reading of $13\mu V$. Using the AF obtained from the SAE ARP approach the field emitted by the EUT is given by $E(dB)=AF(dB)+V(dB)$. Hence the field emitted is $38.3dB_{\mu V/m}$ which is over one decibel lower than the limit level for ground equipment. The equipment will pass the test. However, using the extrapolation range and the computed AF the level is $39.5dB_{\mu V/m}$ right on the limit, causing the equipment to fail the test. More important, the equipment that passes when using the SAE ARP 958 factors is actually emitting a signal that is higher than expected. T

IV. LIMITATIONS OF THE INTERPOLATION RANGE

The results of the interpolation approach to get the gain at 1m follow the computed results for the antenna using (1). But as the data show, as frequency increases the results seem to approach the SAE ARP 958 method measurements. In figure 3 good agreement is shown up to 650MHz. At 650 MHz the far field distance is 6m. That means that less than 50% of the data

captured in the extrapolation range was in the far field region of the antenna.

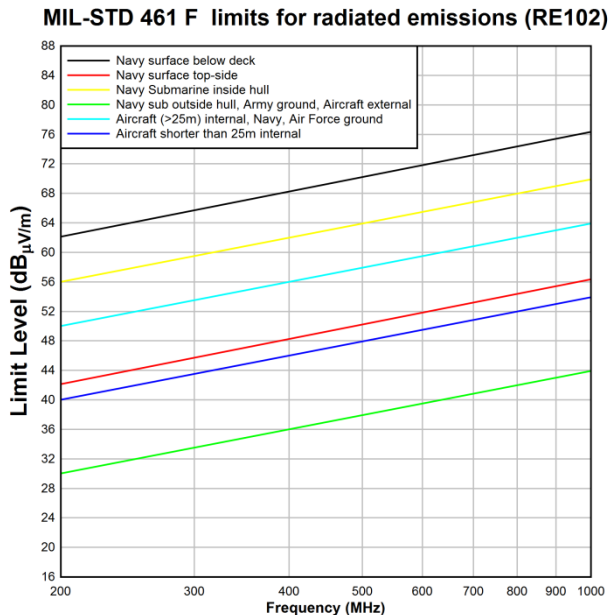


Figure 4. Limit levels according to section RE102 of MIL-STD 461F shown for the frequency range of the dual ridge horn.

Figure 5 shows the extrapolation range data plotted with the far field distance. This seems to point to the limitation of the method. It appears that a percentage of the data gathered in the scan must be in the far field. This issue could limit the use of the method since it will be necessary to have extremely long ranges for performing the calibration. This will drive the cost of the approach.

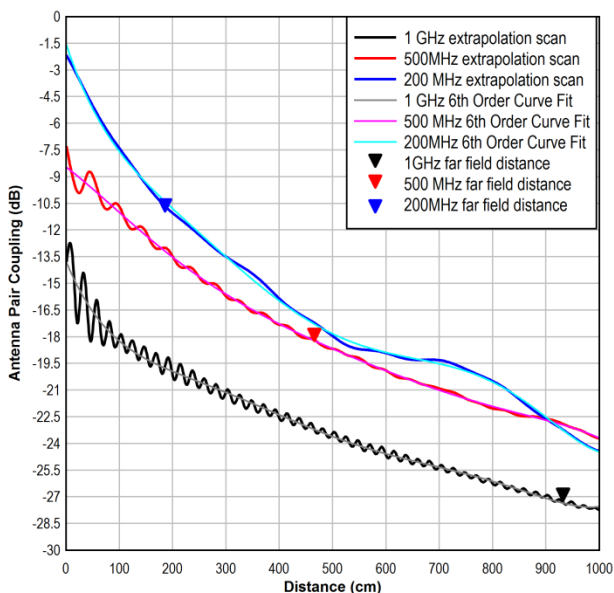


Figure 5. Extrapolation range data at three frequencies plotted with markers showing the far field distance for the typical 200MHz to 1 GHz antenna used in MIL STD 461.

V. CONCLUSIONS

The work presented has shown that the SAE APR 958 document methodology may introduce errors to the gain and AF. The preliminary measurements and computations appear to show that using interpolation on extrapolation range data may eliminate some of the effects of near field coupling between antennas. These effects are not present during standard radiated emission measurements.

Additional work is necessary to investigate this possible method for obtaining the gain and AF characteristics of antennas at distances shorter than the far field. A critical item to solve is to measure the gain following the method of sampling the field at 1 m. This seems an easy approach, but the uncertainty of the field probe, the effects of the shielded anechoic chamber must be carefully explored. In addition other antenna geometries need to be measured using the technique to evaluate the approach.

REFERENCES

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