

LOW LEVEL COUPLING TECHNIQUES FOR THE HIRF CLEARANCE OF AIR SYSTEMS

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Abstract: Current methods for the assessment of military and civil systems for their response to High Intensity Radiated Fields (HIRF) are numerous and varied in their approach. The two principal methods employ either low level techniques for the calculation of transfer functions for extrapolation to high power environments or the use of high power sources specific to the environment to be considered. Low Level Swept (LLS) techniques are commonly used in the certification of both military and civil aircraft to HIRF. This paper examines the Low Level Swept Current (LLSC) technique and demonstrates the effect that the receive antenna height may have on the reference field calibrations. The results of this study show significant variation of up to 10dB may be directly attributed to the electromagnetic test configuration. Moreover, recommendations are made to alleviate measurement uncertainty.

Index Terms— HIRF, EMC in Complex large Systems, EM Environment

I. INTRODUCTION

The requirement for the clearance of aircraft to a specific Electromagnetic Environment (EME) goes back to the early 1930s where the concern was the effect of engine interference with communications systems [1]. Since this time, there have been a number of occurrences directly related to interference as a result of Electromagnetic Compatibility (EMC) issues. One particular occurrence was the severe loss of life as a result of an un-commanded release of stores over the USS Forrestal aircraft carrier in the 1960s [2].

More recently, the functional use of electronics has been increased extensively for critical system functions and this has led to an increasing interest in compatibility issues. It is accepted that the introduction of digital avionics into flight critical functions in aircraft has introduced susceptibilities to external transmitters that exist in the environment [3], [4].

As technology progresses electronic components are being designed with smaller feature sizes that can operate on lower power rails. This impacts on the ability of these future electronics to operate successfully throughout an EME, as it is likely that less EM energy will be required to invoke a susceptibility.

The assessment techniques currently used for evaluation of system response to the EME vary in their methodologies. Low level techniques were developed by those looking specifically into methods of ensuring that aircraft could be cleared to fly through High Intensity Radiated Fields (HIRF) [5]. This method of clearing aircraft for flight has stood the test of time and is used internationally as the preferred technique [6], [7], [8].

Low Level Swept techniques are currently used to remove the need to expose assets to high level of RF radiation. They also identify optimum frequencies for coupling RF energy and allow for the construction of a transfer function on a cable by cable basis.

There is a high level of interest in refinement of these techniques due to their widespread use throughout the aircraft clearance community. Improvements to the technique are being sought primarily to reduce either the time taken to complete an assessment or the overall costs involved [9], [10]. Limitations to the technique include problems using near field radiation to measure induced currents as a result of transmitters that are radiating in the far field and the effect of having the aircraft located on the ground when it will be at altitude when traversing a HIRF area.

Any verifiable improvements that are accepted by the community should result in updates to standards that dictate the test procedures to be followed.

The suitability of Reverberation (Mode Stirred) Chamber assessment for this application is also discussed.

II. A LOW LEVEL SWEEP CURRENT INVESTIGATION

The present LLSC technique uses a single field calibration that is used to normalise the transfer function in terms of incident field. Thus, the transfer function is described in terms of induced current per V/m of incident field. This works well for small systems where the cable looms under investigation are at a similar height to the calibration height. However, as the differences between the calibration height and the height at which the cable loom is monitored become large (as could be the case with larger systems) the profile of the transfer function is likely to change. This is primarily due to the effect of the ground on the field measurement and is only of interest

to the horizontal component of the electric field, as the vertical component will remain largely unchanged. To investigate this behavior, a series of experiments has been conducted to quantify the difference in electric field magnitude for different heights above the ground with the transmitter height remaining constant throughout. Standard Low Level Swept Current (LLSC) equipment was set-up at QinetiQ Farnborough. For the calibration phase, the field was measured using a D-dot sensor 40m from the transmit antenna. The height of the sensor above the ground was varied from 0.5m to 4m in 0.5m steps to allow the effect of receive antenna height to be assessed. The results of the measurements for the three LLSC bands are shown separately in Figures 1 to 6.

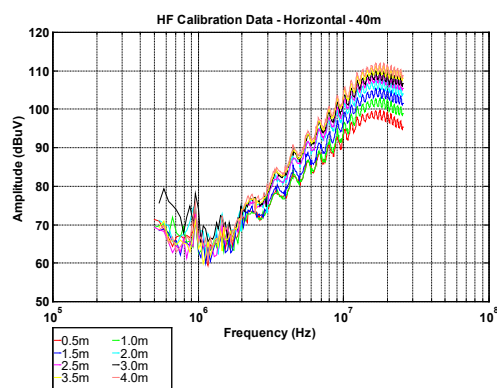


Fig. 1 Horizontal HF Calibration Data

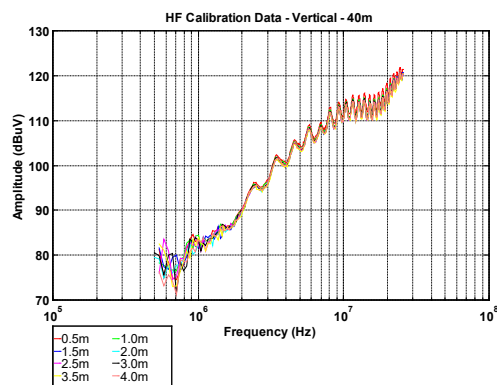


Fig. 2 Vertical HF Calibration Data

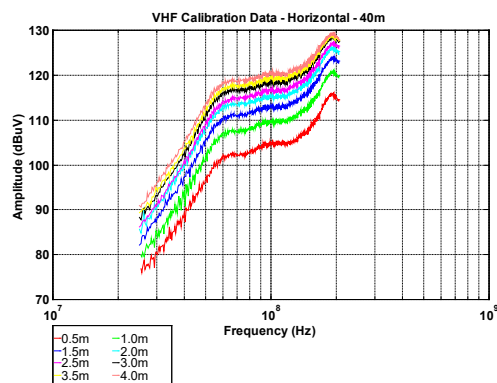


Fig. 3 Horizontal VHF Calibration Data

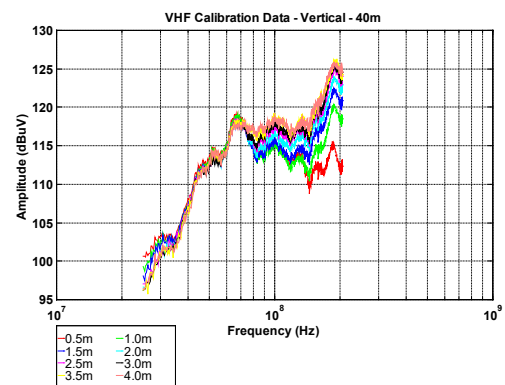


Fig. 4 Vertical VHF Calibration Data

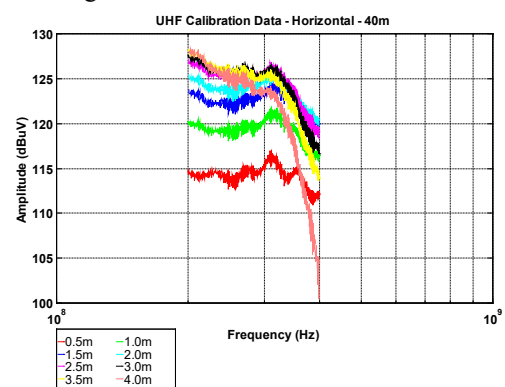


Fig. 5 Horizontal UHF Calibration Data

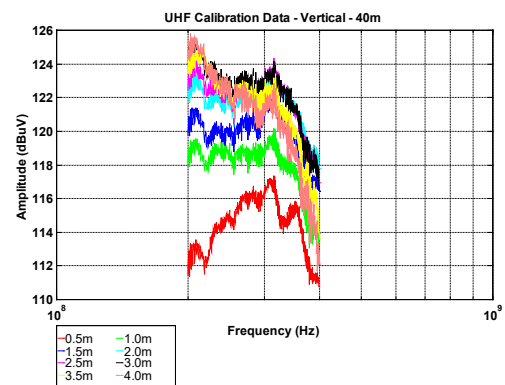


Fig. 6 Vertical UHF Calibration Data

This data shows that the reference field level measured increases as the D-dot height increases. This is observed for the horizontally polarised fields up to approximately 70MHz due to the interaction of the field with the ground. At frequencies in excess of 70MHz the vertical field starts to become receive antenna height dependant. This may be due to the bi-log transmit antenna being made up of two antenna types (bi-conical and log-periodic). As this phase of the assessment requires the measurement of a reference field, this feature does not effect the final result. The important point here is that the same antenna must be capable of reproducing its radiation

pattern when the Equipment Under Test (EUT) is present. This maximum variation for a receive antenna height of between 0.5m to 4m is 15dB.

III. EFFECT ON INDUCED CURRENT MEASUREMENTS

Following the reference field investigations, a selection of cable looms were chosen in a Puma Helicopter. Figure 7 shows the Puma in position with a HF Dipole with RF incident side on to the aircraft.



Fig. 7 Puma Helicopter undergoing assessment

A comparison of the effect of using the reference field calibration at various heights was then conducted to allow quantification of the effect of using an incorrect reference field calibration for this technique. Figures 8 and 9 show the effect of using a reference field that varies by 1m from the height of the measurement point for two different test points on the Puma.

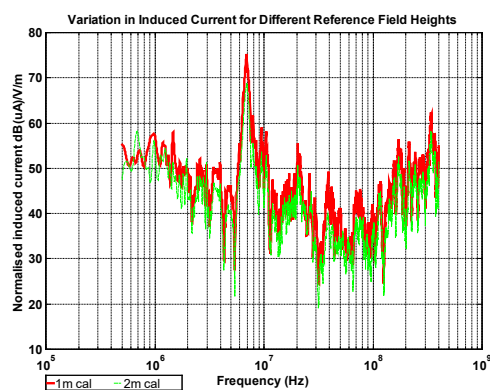


Fig. 8 Transfer function variation – Test Point 1

In this case, the maximum discrepancy is 10dB at 387MHz.

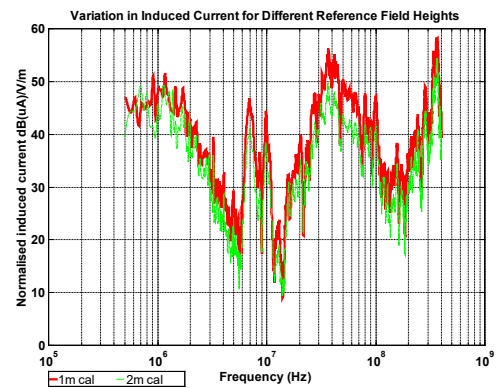


Fig. 9 Transfer function variation – Test Point 2

In this case, the maximum discrepancy is also 10dB but occurs at frequencies of 26MHz and 39MHz.

The data given in Figures 8 and 9 shows that it is essential to ensure that reference field measurements are conducted at a height that is close to that of the induced current measurements that follow on.

This may be especially important when assessing large systems that have distributed cable networks inside them that run over the system. For example, a Tristar aircraft will have cable looms that run to the engine on the tail as well as along the main fuselage of the aircraft. In this case, multiple reference fields are recommended to reduce uncertainties in the final result.

IV. CONVOLUTION WITH THREAT WAVEFORM

The final stage of this investigation involved convolution of the induced currents with a typical RF environment to identify any over or under prediction that may occur as a result of using an incorrect calibration height. This process was completed with the use of the DREAM signal processing and trials analysis software developed by QinetiQ [11].

Figures 10 and 11 show the result of convolving a 50MHz damped sine with the transfer functions given in Figures 8 and 9 respectively.

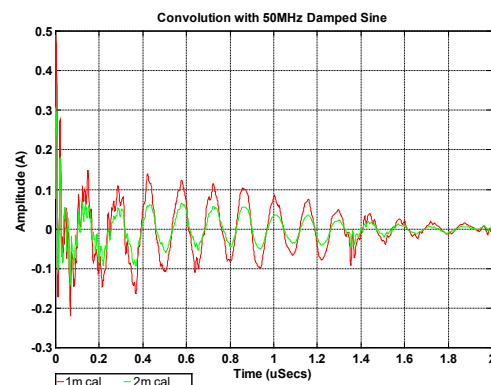


Fig. 10 Convolution results –Test Point 1

As expected, the response of the convolution is dictated by the resonance of the system measured, in this case, 6.8MHz. As can be seen, the maximum difference as a result of convolution with this environment is 7dB.

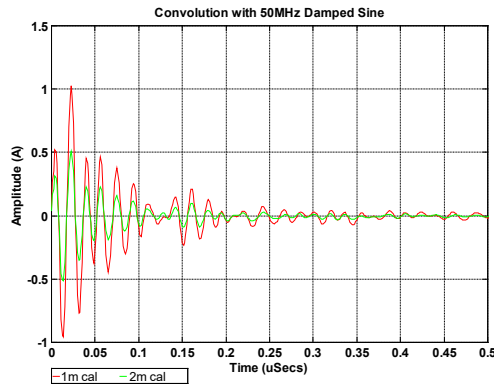


Fig. 11 Convolution results –Test Point 2

Again, the response is dictated by the peak resonance frequencies recorded in the transfer function. For Test Point 2, resonant frequencies exist at 6.8MHz and at 36.8MHz, as a result of this the response of the predicted current waveform has different frequency content and a larger peak amplitude. This is because the 50MHz damped sine environment is close to the 36.8MHz resonance and as such a larger transfer of energy occurs. The maximum difference as a result of convolution of Test Point 2 with this environment is 6dB.

V. ALTERNATIVE TECHNIQUES

Alternative techniques to LLSC may include using a reverberation chamber to measure the transfer function. However, the primary limitation here is that the size of the EUT dictates the size of chamber required. The LLSC technique is used primarily for aircraft assessment and has been used successfully on a Boeing 747. A very large reverberation chamber would be required to accommodate an aircraft of this size, as a result of this, a large power requirement would exist in order to generate the power density required to uniformly radiate at 1V/m across the EUT. In addition to this, the lowest achievable frequency in a reverberation chamber is dictated by its largest dimension. Therefore, to achieve 500kHz (as with the current LLSC technique) the reverberation chambers largest dimension would have to be approximately 600m (i.e. 1 wavelength). Also, the use of a reverberation chamber would not overcome the issue of near field radiation being used for far field. The Low Level Direct Drive (LLDD) or Direct Current Injection (DCI) technique could be used to gain transfer function data for low frequencies. This technique uses the direct attachment of an injection

point to the EUT at the nose with a return point being taken at the rear. Current flows along the skin of the EUT and the cable looms of interest are monitored by the same method as for LLSC. The LLDD has been used from low kHz to 30MHz and overcomes the problem of inefficient HF dipole radiation between 500kHz and 2MHz, a common problem with the current LLSC technique.

VI. CONCLUSIONS AND RECOMMENDATIONS

This paper has demonstrated the importance of making reference field measurements at a comparable height to that of the cable loom to be measured. This work has demonstrated that it is essential to have the reference field heights comparable to the current probe heights. Failure to do so may result in large errors in the predicted current profiles with up to 10dB for a 1m difference. This difference becomes larger as the distance between calibration height and measurement height increases. If this practice is observed, the uncertainty associated with the prediction will then be principally dependant on the measurement technique and not as a result of variations in the EME.

VII. ACKNOWLEDGEMENTS

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