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DEMONSTRATION OF EMC COMPLIANCE ON THE EH101 HELICOPTER FOR MILITARY AND CIVIL REQUIREMENTS

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1. Abstract

In November 1994 the EH101 Heliliner attained Type Certification from the CAA, RAI and FAA. This represents a significant achievement, especially in view of the differing requirements of the European and American authorities. In 1995 the Royal Navy variant of the EH101, the Merlin, successfully underwent testing to Stanag 4234 levels. Both of these achievements represent the culmination of comprehensive EMC programmes aimed at developing a helicopter that can operate in harsh electromagnetic environments.

The EMC High-Intensity Radiated Field (HIRF) requirements for a modern helicopter are some of the most severe for any aircraft. These reflect the ability to hover for long durations while exposed to high-level electromagnetic fields combined with low-level flight and the ability to fly into areas traditionally avoided by fixed-wing aircraft.

This paper presents a helicopter manufacturer's perspective on the HIRF clearance process. It details some of the lessons learnt and proposes solutions to the problems facing all of the aerospace industry, but in particular the helicopter sector. The HIRF clearance forms part of an overall EMC programme which covers all aspects including equipment specification and qualification testing and radio interference assessments. However, HIRF has become the most critical aspect of qualification and this paper concentrates solely on this issue.

The current state of affairs makes achieving a HIRF clearance for a helicopter a particularly arduous process. A combination of a high external environment and low attenuation on some parts of the aircraft make the protection of aircraft systems and personnel difficult and has lead to testability limits that have had to be overcome. This paper presents an analysis of the situation and proposes options for ensuring the safety of personnel and enhancing the test techniques.

The paper finally discusses the situation with regards to the European EMC Directive, and its potential impact upon the aerospace industry.

2. Background To The HIRF Environment

During the development life-time of the EH101, the HIRF clearance environment has changed dramatically. In the late 1980's the civil certification authorities recognised the need for a standardised approach to certification of aircraft and a rationalisation of the environment. Committees and working groups were tasked to achieve this, but the rapid changes of technology and the environment (and the difficulty in obtaining international agreement) mean that this is still ongoing.

The EH101 has been cleared to an interim standard, based on JAA recommendations and FAA specific requirements. Further information on the civil aircraft HIRF specification can be found in the EUROCAE Users Guide[1]. The source of the environment and, as a result, the problem of fixing the definition of the environment stems from

- a worst-case survey of the transmitters around the world combined with
- a set of radii which define how close to a transmitter an aircraft is to be able to fly.

The military versions of the EH101 have been tested to the Stanag 4234 environment which defines the operational environment the aircraft encounter in use.

Both of these clearance environments are shown in Figure 1 overleaf:

At frequencies below 400 MHz, the test techniques are common to both the civil and military variants. Low Level Sweep was used to determine the currents induced on the aircraft cablelooms when the aircraft was illuminated by a low level electromagnetic field. These currents were then extrapolated to predict the currents that would be induced in the required environment and Bulk Current Injection was used to allow the systems to be assessed.

The two programmes diverged above 200 MHz where radiated testing is necessary. The civil clearance method used airframe attenuation measurements to determine the aircraft's internal environment and then radiated susceptibility testing on the aircraft to stress the equipment. The military programme, however, used the Radio Frequency Environment Generator (REG) at A&AEE, Boscombe Down to provide a whole aircraft assessment at the required environment.

3.1. Civil Clearance

The EH101 Heliliner achieved Type Certification from the CAA, RAI and FAA in November 1994. This, the first major stage in the overall certification process, has been completed as a result of an exhaustive assessment of the performance of the aircraft systems when exposed to the HIRF environment using a pre-production aircraft. All flight-critical and essential systems have been subjected to the required environment, but current test techniques were often pushed to the limits.

In areas such as the cockpit and transmission deck, achieving a high level of shielding is especially difficult. The formation of standing waves from the largely unattenuated environment can lead to enhancements of the field strengths, giving test levels higher than those shown in Figure 1. As a result, when performing radiated susceptibility testing on systems on the aircraft, while the average field is easily achievable, the peak values are at the limits of the test equipment.

More importantly, the personnel on board (required to stimulate and assess the systems under test) are potentially subjected to an average environment vastly exceeding the recommended exposure levels. In addition to the obvious exposure risks during radiated susceptibility testing, similar risks exist during conducted susceptibility tests (Bulk Current Injection, BCI), performed below 400 MHz. With high powers being injected onto the aircraft cablelooms, the resultant radiated fields may also exceed the biological safety limits. In response to this, monitoring the radiated environment, and thus protecting the test engineers, has become standard practice at WHL.

3.2. Military Clearance

The Royal Navy variant of the EH101, the Merlin, underwent its final development testing at the Radio-frequency Environment Generator (REG) in February of this year. During a trial lasting for a month, the aircraft was subjected to the levels defined by the Stanag 4234 environment.

The Merlin was the first aircraft to be subjected to the higher levels available at the updated REG. The testing proved the operation of the whole aircraft as an integrated system, with most of the tests being performed with the aircraft under its own power with rotors turning. The philosophy used was to start with the "core" avionics systems, such as the electronic display and engine control systems, to ensure that the aircraft was functioning correctly. As confidence was increased, further systems were included until the final tests, which demonstrated the aircraft operating as a whole.

The REG provides the most accurate representation of the required operating environment. The HF facility provides whole-aircraft radiated coverage up to the military requirements while the microwave facility allows peak field strengths of the order of 20kV/m to be generated. Testing at the REG provides the final confidence check that the aircraft design and build are correct. The facility does, however, have two limitations:

- As only spot frequencies are available, it is not possible to explore areas of susceptibility to determine the frequency profile of failures.
- In the microwave band, the 3 dB beam widths are relatively small, which reduces the volume of equipment that can be tested in a single run. In addition, the antenna system is outside the aircraft and is relatively fixed in terms of illumination direction when compared to the radiated susceptibility testing undertaken on the civil variant.

In order to ensure operator safety, a comprehensive mapping of the environment inside the aircraft was undertaken. This demonstrated the expected reduced levels inside the main cabin area where the airframe is of metal construction, while from some illumination directions, the cockpit offered lower attenuation. As a result, exposure-management was employed, with exposures being limited, in some cases, to as little as 45 seconds in a 6 minute period. The impact of this limitation upon the test time

4.2. Equipment Testability

As already mentioned screening offered by the primarily metallic fuselage structure is considerably reduced by windows, doors, access panels and ventilation apertures. The two most significant low attenuation areas are

- the cockpit, where the large areas of non-conductive transparency mean that the internal environment is high, and
- the transmission deck, where the engine intake and exhaust, main rotor-head aperture and maintenance access requirements prevent the use of the optimum screening techniques.

The introduction of digital flight-safety critical systems in these very areas, such as Electronic Flight Information Systems (EFIS) and Full-Authority Digital Engine Control (FADEC), increases the importance of safety. Future developments, e.g. "smart" main rotor heads, will further increase the quantity of electronics in relatively exposed locations on the aircraft.

In both of these areas, the low attenuation results in high internal field strengths. The radiated susceptibility test facilities currently available are being run at their maximum potential to reach the peak field strengths required. If any further increase in the environment is to be accommodated, significant development and investment in the test facilities will be required.

This does, however, raise a major difference between the military and civil authorities:

- For the military the aircraft will be tested to the highest available levels in the UK.
- The civil authorities do not limit the clearance requirements when the test facility is not able to reach the required levels. Instead, improvements to the attenuation are required which, as will be discussed, may be impossible to achieve.

In addition to the solutions listed in the previous section aimed at reducing the internal environment, changes to the test techniques may be possible.

5. Recommendations For Future HIRF Clearances

5.1. Shielding Performance

It is generally stated that the attenuation afforded by modern airframes has been reduced by the replacement of metal with composite materials. However, even where metal is used as the primary structure, the presence of ventilation apertures, doors and windows violate the screen. Improvements to the shielding for fixed windows (including the windscreen) is relatively simple to achieve as the electrical connection is permanent. Even with this case, however, there is a trade-off between shielding performance and transparency, which limits the level of attenuation that can realistically be achieved.

Improving the shielding performance of doors and opening windows is extremely difficult, requiring a microwave seal such as a "finger" seal. The transmission deck, with large opening panels required for maintenance access, presents a significant problem. Gaskets and finger seals are suited to relatively clean areas where the shielding measures can be maintained in good condition. Quick-release catches are far from ideal for achieving a good microwave seal around panels, but are necessary for rapid access. In addition to the problems with maintenance, corrosion of the metal surfaces, particularly for naval aircraft, exacerbate the situation.

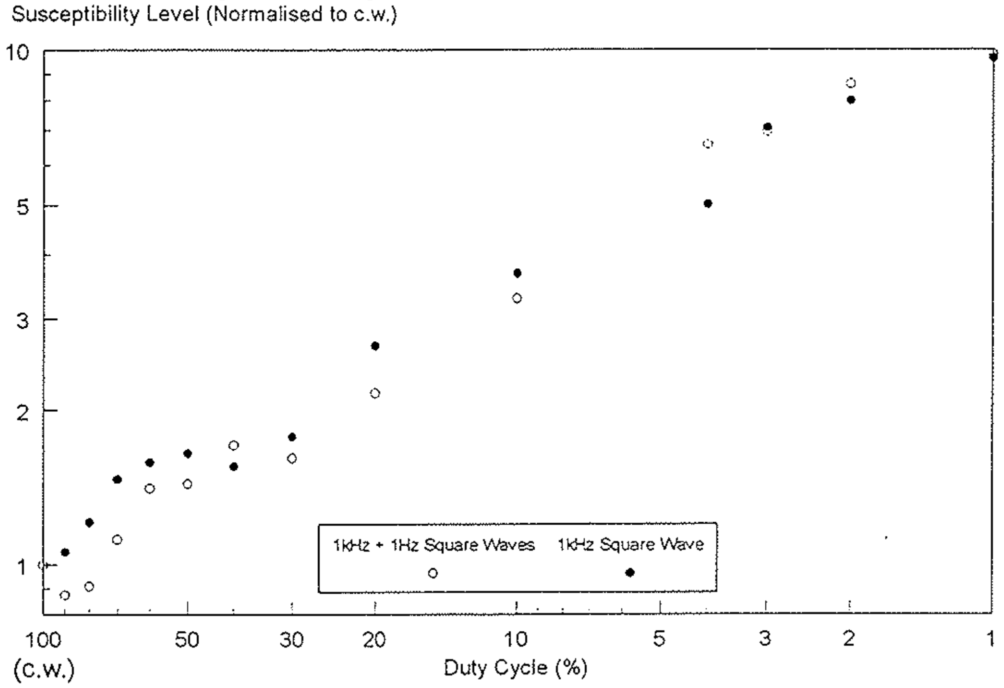
Even if the panel edges were sealed to microwave frequencies, the presence of the engine intake and exhaust, rotor shaft and head and large airflow cooling vents prevent an overall seal from being achieved. These apertures cannot be sealed and therefore form a fundamental limitation on the attenuation available on the transmission deck.

Consequently, improvements to the airframe shielding are not capable of reducing the internal environment completely. The remaining option for reducing the environment, if test techniques are unchanged, is to ensure that the aircraft is not exposed to an environment that will either degrade the avionics or present a biological hazard to the crew and passengers.

5.2. Exclusion Zone Database

Based on the UK armed forces HIRTA (High-Intensity Radio Transmission Areas) system, every transmitter above a specified power level could be registered and an exclusion zone defined in terms of a horizontal radius and altitude. By determining a set of exclusion zones, the EM hardness of

Figure 3: Investigation into Peak / Average Power Dependency



While being able to demonstrate that the failure profile of a system is average-power dependent would not reduce the biological exposure (the limits are based on average levels), the problem of achieving the peak field strengths is removed.

Unfortunately, it would still be necessary to test to the peak environment when peak-power dependence is found or where a system shows no susceptibility (i.e. it is not possible to demonstrate that it is average-power dependent).

5.4.2. Screened Room Testing vs. On-Aircraft Testing

If high test levels are required for an aircraft clearance, the easiest route to reducing the biological exposure risk is to perform the testing in a screened room. This does mean that the system is not in its exact installed configuration. However, as the test frequency increases, the natural attenuation of cables and shortening wavelengths translate the source of HIRF problems away from cable conduction to direct penetration of the system enclosures. This means that screened room testing becomes more representative of the installed configuration tests as the frequency increases.

As part of an investigation programme, several systems were tested both on the aircraft and in the EMC laboratory. The laboratory tests were performed in a stirred-mode chamber which uses rotating metal paddles to move the resonances of the screened room such that all points of the system under test will see the peak field strength. The aircraft testing also used stirred mode testing, but the proportion of stirred energy was lower than the laboratory tests.

The results obtained showed that the systems tested failed at a lower field strength in the laboratory. Assessments of the techniques have concluded that the differences in the levels are due to:

- The higher ratio of stirred to unstirred radiated energy in the screened room.
- In the laboratory, all aspects of the equipment under test (apart from the lower surface) are exposed to the radiated field, while on the aircraft, the presence of cabinets and other systems can protect some aspects.

If further testing can be undertaken to confirm these initial findings, screened room tests may be able to replace on aircraft testing, thereby reducing the exposure of test engineers.

6. The European Directive

The European Directive on EMC (89/336/EMC) is implemented in law in the member states with mandatory compliance commencing on 1st January 1996. At the time of writing, commercial aircraft and aircraft systems will have to be compliant with the EC Directive, although no standards for aerospace equipment and complete aircraft are defined. The case for military aircraft, which until recently were considered to be excluded under the Treaty of Rome, is still unsettled. It is ironic that