A Hypothetical Assessment

Susceptibility of 1A/1W Electro-Explosive Devices in the ADF Baseline RF Environment

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1. Electro-Explosive Devices
Electro-Explosive Devices (EEDs)

- An electro-explosive device (EED) is a discrete device that contains (or is in contact with) an energetic material, and initiates, by design, under application of an electrical stimulus - regardless of its source!
2. Maximum No-Fire Stimulus
Maximum No-Fire Stimulus (MNFS)

• Parameters such as current, power and energy are used to define no-fire threshold data for EEDs.
• The maximum no-fire current (MNFC) results in no more than 0.1% of EEDs firing (with 95% confidence level).

Example:

MNFC: 100mA
all-fire current: 350mA
bridgewire resistance: 1Ω
3. 1A/1W EEDs
1A/1W Electro-Explosive Devices

- Will not initiate when subjected to a current of at least 1A for 5 minutes with an associated power of at least 1W.
- Demonstrated ability to safely dissipate the said power without firing.
- Inherently, these devices are less susceptible when subjected to electrical stimuli.
- The 1A/1W criteria is not a true no-fire threshold per the definition provided earlier.
- Accepted practice to use MNFC = 1A and maximum no-fire power (MNFP) = 1W.

Illustrative Example:

Significant safety margin

Small safety margin

Illustrative Example:
4. Theoretical Analysis
Theoretical Analysis

- The antenna effective area \( (A_e) \) can be written in terms of the antenna’s gain factor \((G)\) and the wavelength \((\lambda)\) of the incident signal as follows:

\[
A_e = \frac{\lambda^2}{4\pi} G
\]

- \( A_e \) represents the area of the incident wavefront that is ‘captured’ by the receive antenna.
- The power received by the antenna can be expressed in terms of the incident electric field strength \((E_{\text{incident}})\) as follows:

\[
P_{\text{received}} = \frac{E_{\text{incident}}^2}{377} (A_e) = \frac{E_{\text{incident}}^2}{377} \left( \frac{\lambda^2}{4\pi} G \right)
\]

Note: 377Ω represents the impedance of free space.
Effective Area – Illustrative Example

• The effective area \( (A_e) \) of a dipole antenna can be written as follows:

\[
A_e = \frac{\lambda^2}{4\pi} (1.64) = 0.13\lambda^2
\]

Observations:

• With the gain factor fixed, \( A_e \) is dependent only on \( \lambda \).
• \( A_e \) can be approximated by a rectangle with dimensions shown.
• As the wavelength reduces, \( A_e \) reduces.

\[
\text{Area} = \left(\frac{\lambda}{2}\right) \left(\frac{\lambda}{4}\right) = 0.125\lambda^2
\]
Theoretical Analysis - Continued

The shown expression can be rewritten to determine the incident electric field strength, resulting in 1W received power ($P_{\text{received}}$):

$$P_{\text{received}} = \frac{E_{\text{incident}}^2}{377} (0.13\lambda^2)$$

- The shown expression can be rewritten to determine the incident electric field strength, resulting in 1W received power ($P_{\text{received}}$):

$$E_{\text{incident}} = \sqrt{\frac{377 \times P_{\text{received}}}{0.13\lambda^2}} = \sqrt{\frac{377 \times 1}{0.13\lambda^2}} = \frac{53.85}{\lambda}$$

Observation: As the wavelength reduces (with increasing frequency), the incident electric field strength required to induce 1W increases.
5. ADF Baseline RF Environment
The ADF Baseline RF Environment
6. Contextualisation
Contextualisation

**Approach:** Determine electric field strengths across associated frequency bands that result in 1W being induced in the 1A/1W EED.

**Assumptions:**

- consider an EED, connected to a dipole antenna;
- antenna dimensions are optimised based on incident signal wavelength;
- respective EED-antenna combinations are perfectly matched (i.e. impedance and polarisation);
- the EED-antenna combination is not subjected to any form of screening, or shielding;
- safety margins are taken as 0dB;
- an antenna gain of 2.15dBi (or gain factor of 1.64) is used in calculations; and
- far field conditions apply
7. Graphical Comparisons
Graphical Comparison

FIELD STRENGTH (V/m)

FIELD STRENGTH RESULTING IN 1W RECEIVED POWER

ADF BASELINE RF ENVIRONMENT

>1W induced due to ADF Baseline RF Environment

$E_{\text{incident}} = \frac{53.85}{\lambda}$

3.6GHz
Graphical Comparison of MNFP

- **FIELD STRENGTH RESULTING IN 1W RECEIVED POWER**
- **ADF BASELINE RF ENVIRONMENT**
- **FIELD STRENGTH RESULTING IN 100mW RECEIVED POWER**

- **>100mW induced due to ADF Baseline RF Environment**
- **<100mW induced due to ADF Baseline RF Environment**
7. Synopsis & Conclusion
• As $\lambda$ reduces (with increasing frequency), $A_e$ reduces and less power is induced in an EED for a specific $E_{\text{incident}}$.

• Consequently, as $\lambda$ reduces, $E_{\text{incident}}$ required to induce 1W increases.

• For the specific hypothetical pick-up scenario, a 1A/1W device would be particularly susceptible to the ADF Baseline RF environment for frequencies up to 3.6GHz (i.e. $\lambda \geq 8.33\text{cm}$).

• The aforementioned emphasises the fact that the length of firing leads should be kept to a minimum to reduce RF pick-up.

• As expected, EEDs with a lower no-fire threshold power have been shown to be more susceptible to the ADF Baseline RF Environment – but also over a wider frequency range.
To measure, is to know!