Australian Government
Department of Defence
Guided Weapons and
Explosive Ordnance Group

Hazardous Currents/Voltages in Loop-type Structures

Concerns for Explosive Ordnance Handling Operations

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Agenda

- The Interoperability Objective
- The EO Safety and Suitability for Service Challenge
- The Hazard Description
- Incidents
- Bridgewire Electro-explosive Device Operation
- Dipole Antennas, Folded Dipole Antennas & Loop-type Structures
- Arcing
- Maximum Extractable Power from an LTS
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- Conclusion

The Interoperability Objective

Interoperability Definition

"…the ability of different forces to operate safely and effectively together in joint or combined operations."

- In a Defence context, the interoperability concept applies to a vast array of operations.
- In this presentation: an emphasis on Explosive Ordnance (EO) handling and (un)loading operations with cranes and other EO handling equipment.

Reference: Chapter 3 – Australian Force Structure, Interoperability and Intelligence, https://www.aph.gov.au/Parliamentary_Business/Committees/Joint/Completed_Inquiries/jfadt/usrelations/chapter3

The S3 Challenge - EEH Perspective

- It's becoming increasingly complex and challenging to assure the Safety and Suitability for Service (S3) of complex and non-complex EO.
- Electrically initiated EO items are of particular concern. This class of EO has one or more Electro-explosive Devices (EEDs) installed.
- EEDs will function when exposed to any electrical stimulus with a suitable amplitude and duration.
- EEDs may be inadvertently initiated when exposed to an Electro-explosive Hazard (EEH) such as Radio Frequency (RF) radiation, electrostatic discharge, lightning etc.

Hazard Description

- Of particular concern is a hazard relating to RF radiation, namely the RF-induced currents (and voltages) in Loop-type Structures (LTSs) e.g. cranes and EO handling equipment.

Aim

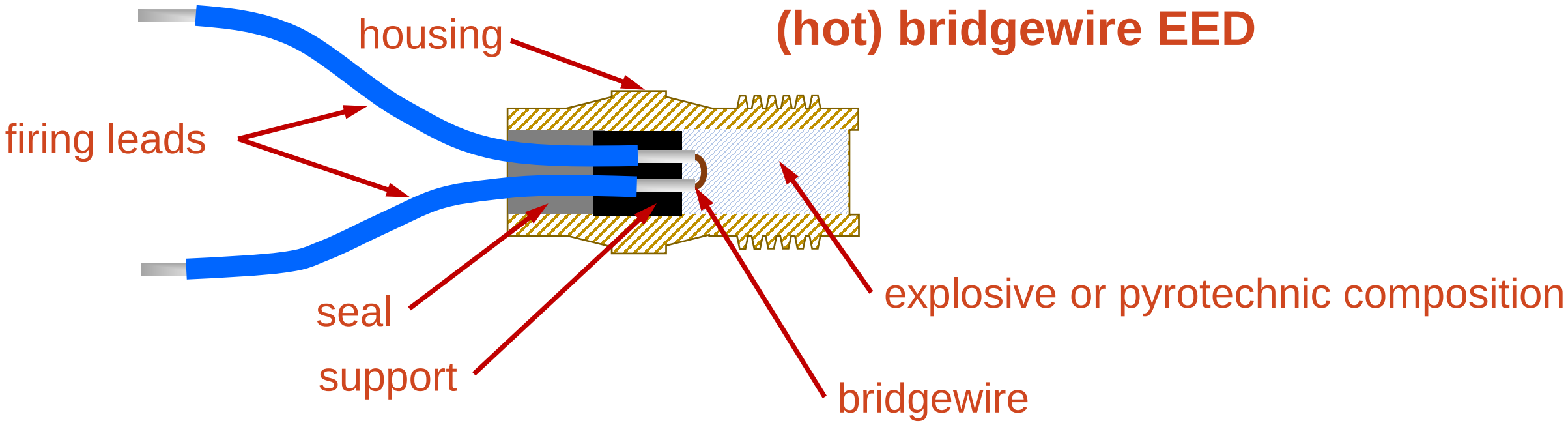
Creating increased awareness about an electro-explosive hazard that may go unnoticed, merely because it may already be effectively mitigated by extant RF Radiation Hazards (RADHAZ) to Ordnance control measures.

Incidents – Hazardous Voltages/Currents on Cranes

LTS Description	RF Emitter	Consequence
Crane with 33.5m boom length.	5 AM channels & 1 FM channel, broadcast across 30-100MHz @ 117kW, 122m antenna height	Ground crew experienced electrical shocks when crane operator lowered steel pilings into a canal. Induced currents of 200mA to 1A were measured. * 200mA is enough current to cause heart palpitations.
Cargo crane at pier.	AM radio station	10V/m in vicinity of cargo ship. 300V open circuit voltage between cable end and ground. Spark discharges occurred upon grasping, which resulted in burns.

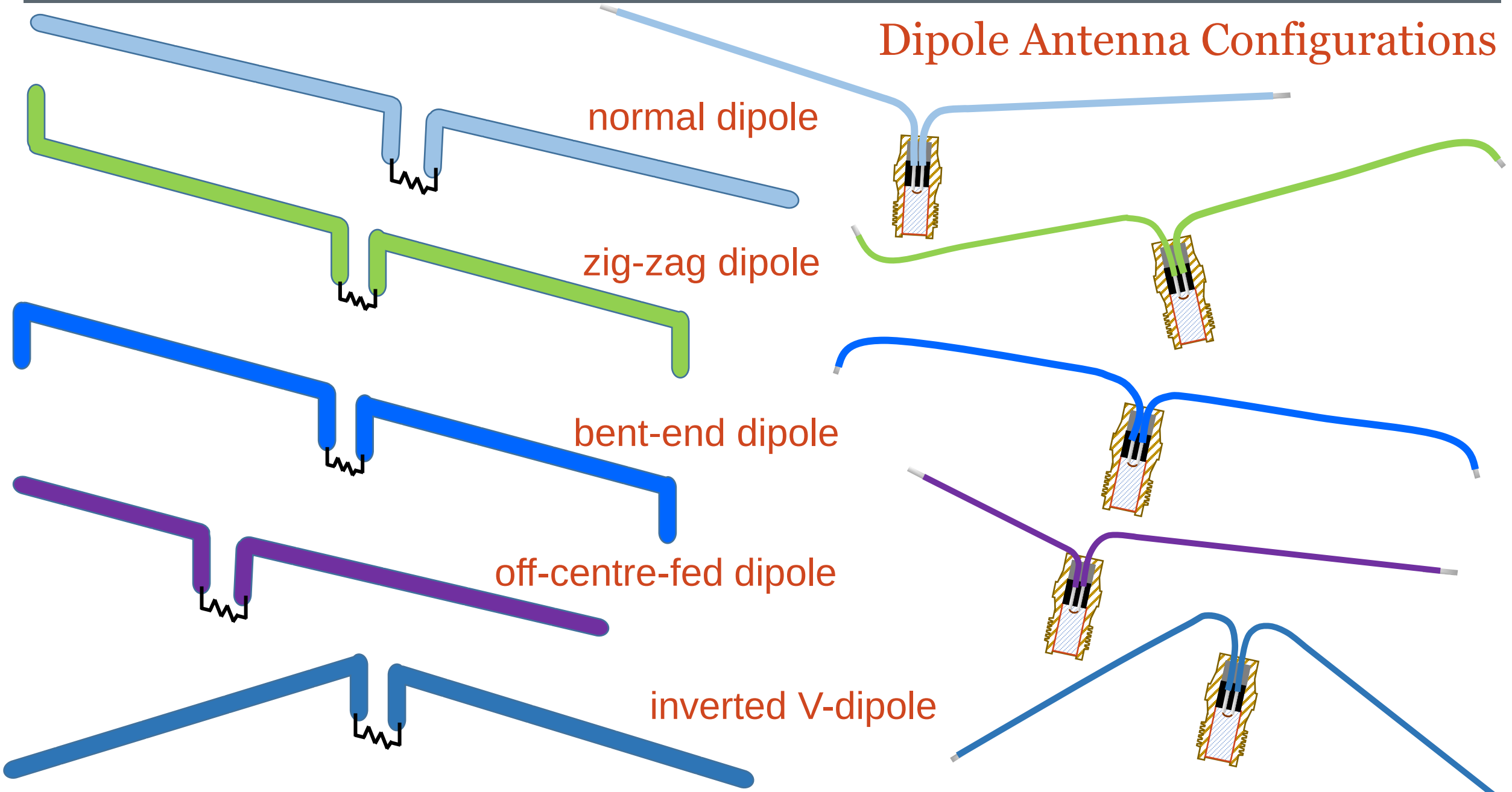
References: T. Denton, Radiofrequency Energy Poses Unseen Hazard of 12 Dec 02, https://www.ehstoday.com/safety/article/21906011/radiofrequency-energy-poses-unseen-hazard
V. Javor, Electromagnetic Interferences between Cranes and Broadcasting Antennas, International Journal of Antennas and Propagation, Vol 2015, Article ID 452962, http://dx.doi.org/10.1155/2015/452962

The Normal Bridge Heating Mechanism



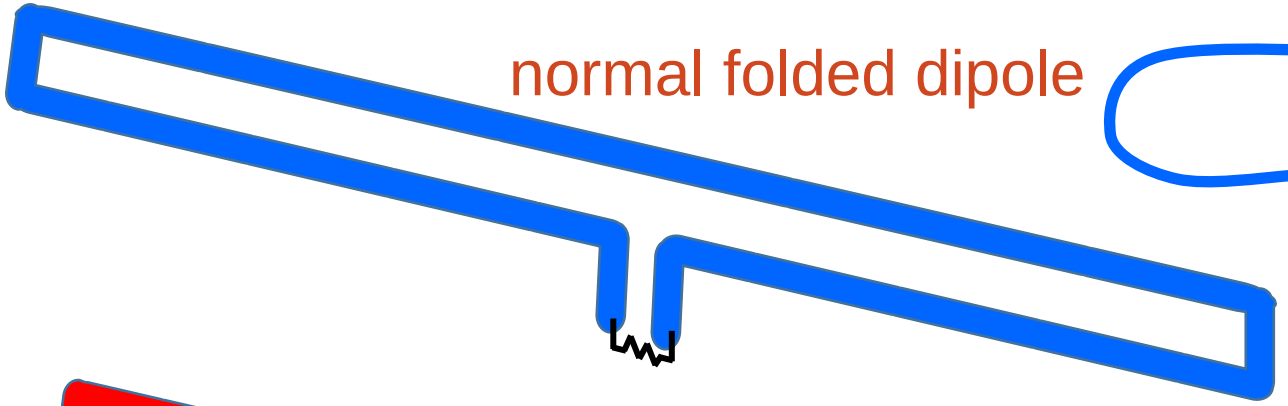
- When an electrical current of suitable amplitude and duration is applied across the resistive bridgewire, it starts to heat to the point where the localised critical temperature of the explosive or pyrotechnic composition is reached. Initiation of the EED then occurs.

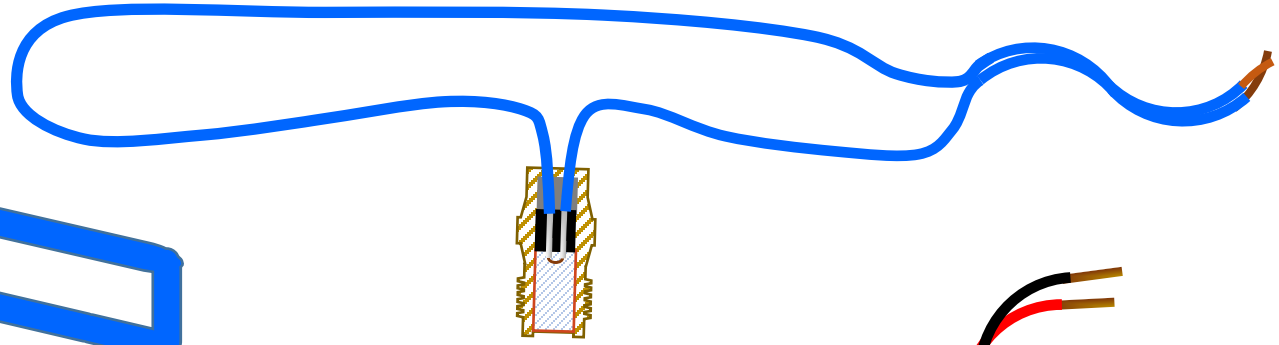
Dipole Antenna Configurations



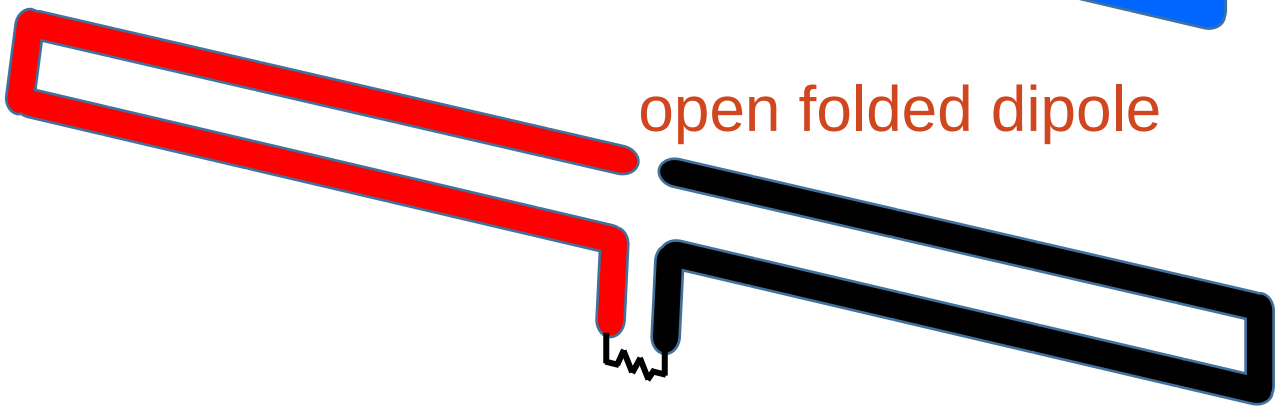
Folded Dipole Types

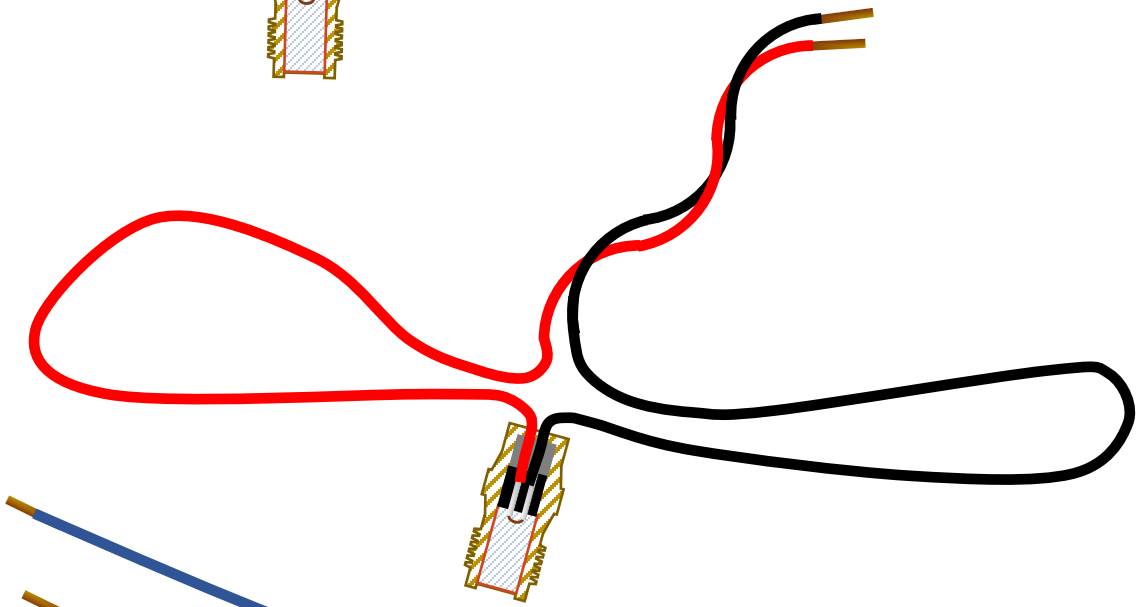
normal folded dipole



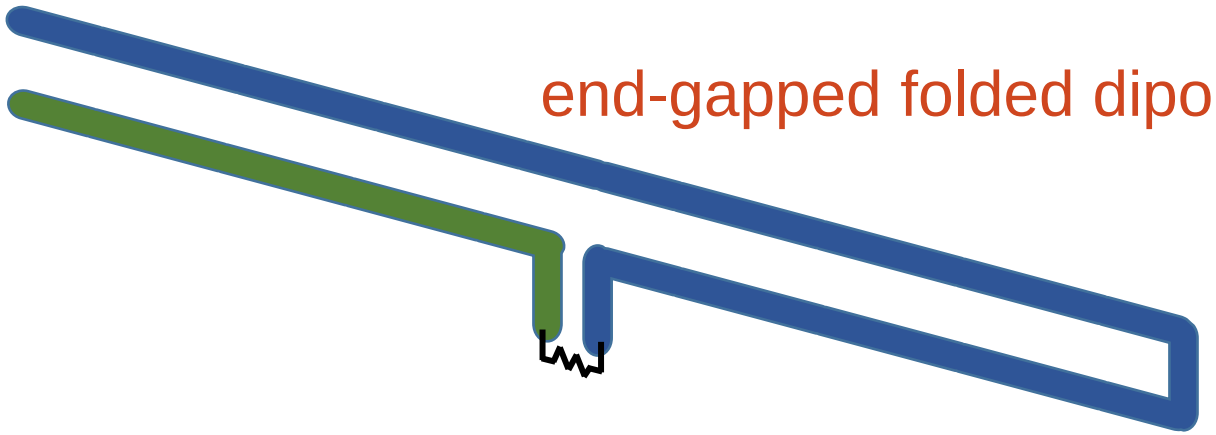


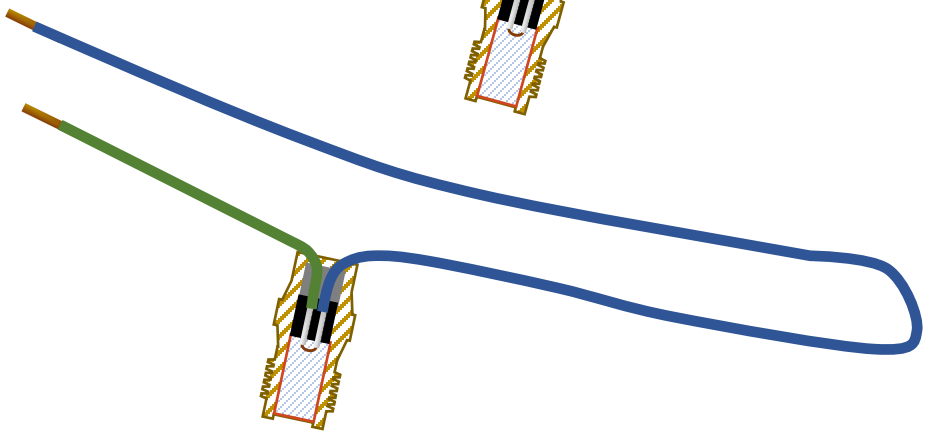
open folded dipole



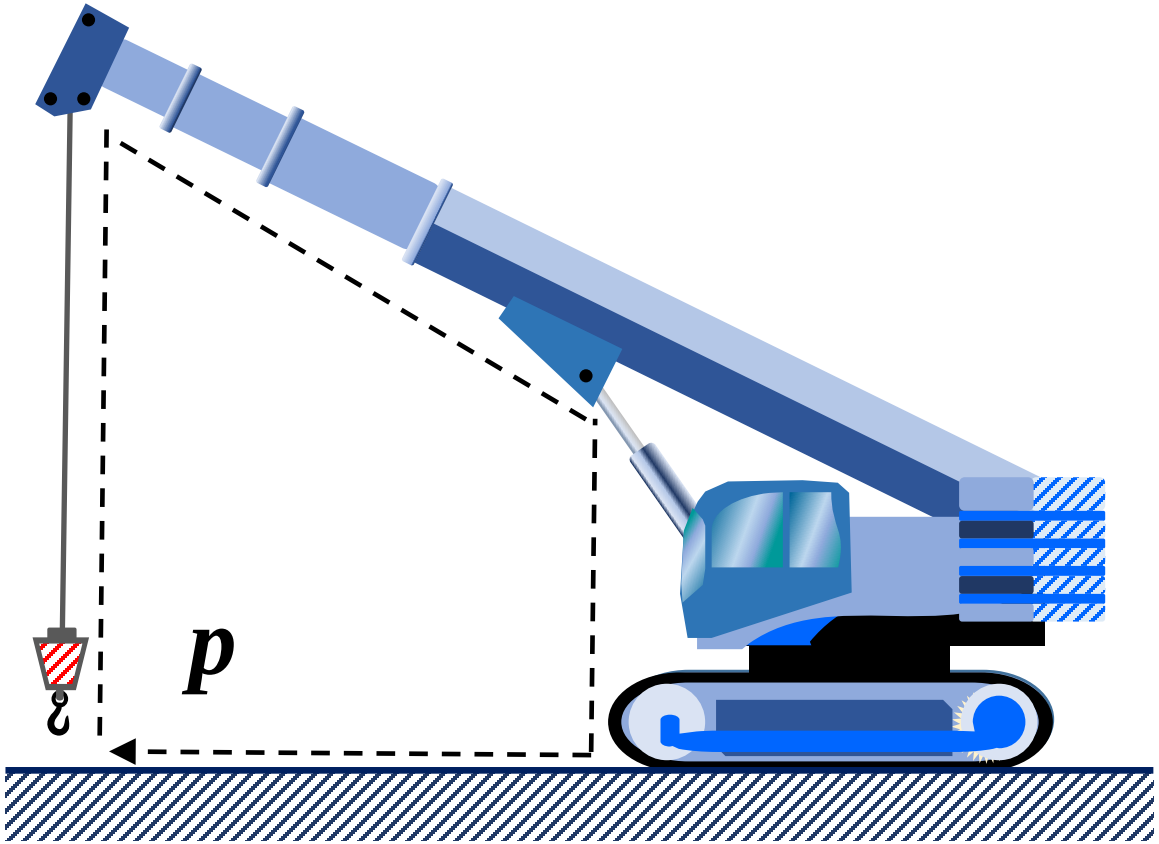


end-gapped folded dipole

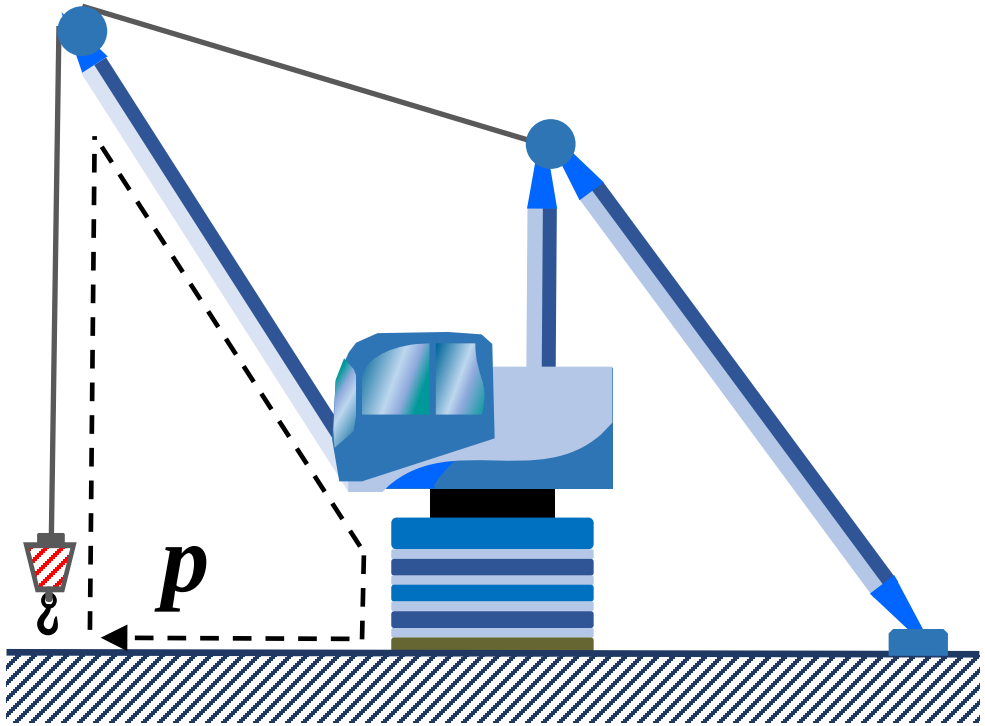




Loop-type Structure (LTS) Examples



telescopic crawler crane



fixed crane

- ***p*** is the inside perimeter of the LTS, as shown.

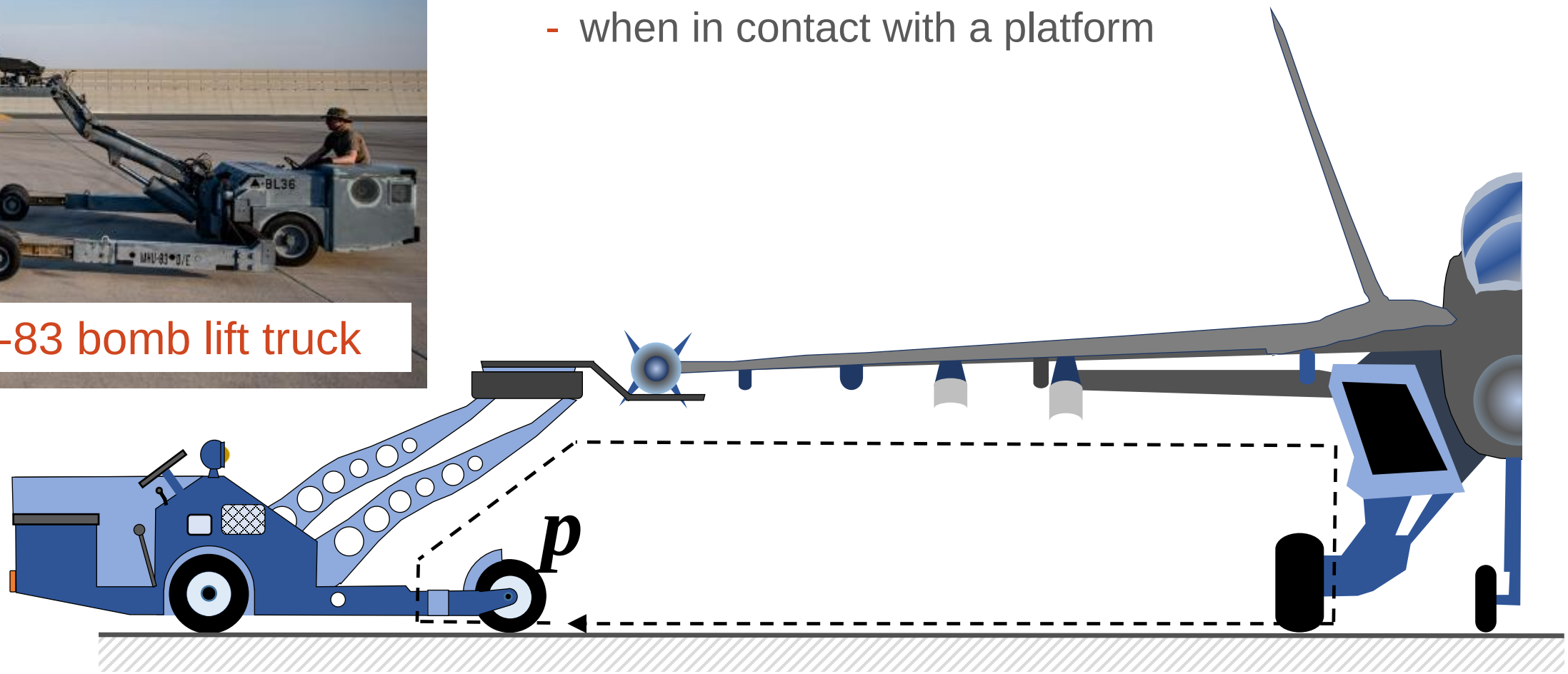
Crawler Crane used for Loading SM-2 Canister

Re-ammunitioning of USS Dewey at the Port of Darwin.

Another LTS Example

MHU-83 bomb lift truck

- LTS formed by EO handling equipment:
  - on their own, or
  - when in contact with a platform



Arcing Video 1

- Arcing occurs when an earthed ground strap is brought near an energised crane cable and its hook.
- Due to a nearby high-power AM transmitter.

Reference: https://youtube.com/shorts/s8DEnhEMl34?si=Ay3toAlbmHwRE98L

Arcing Video 2

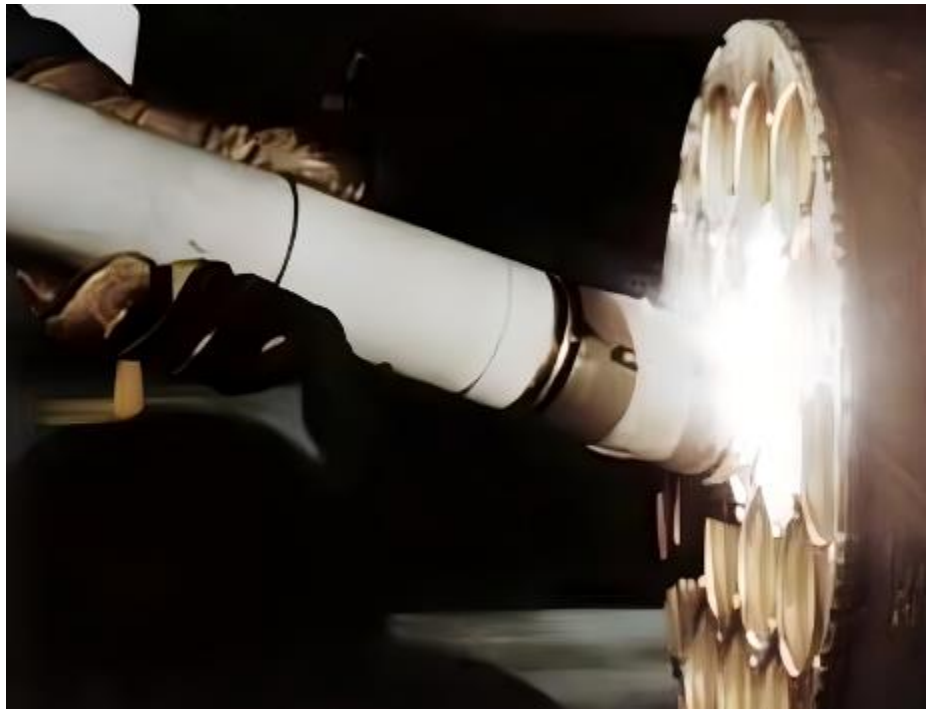
Reference: https://youtu.be/su8zZjNDlqw?si=ZzOL61dPnxuwCN1O

Arcing at Fence Gate Near 50kW AM Transmitter

- 50kW 1120 kHz KMOX AM broadcast tower, Pontoon Beach, Illinois

References: https://www.jeffgeerling.com/blog/2023/mighty-mox-50kw-am-tower-site-tour
https://www.youtube.com/c/JeffGeerling, https://youtube.com/shorts/SjOBDdgcZrc?si=1q2dcUSYRMud97Fi

Arcing during HERO Testing



Arcing during HERO Testing

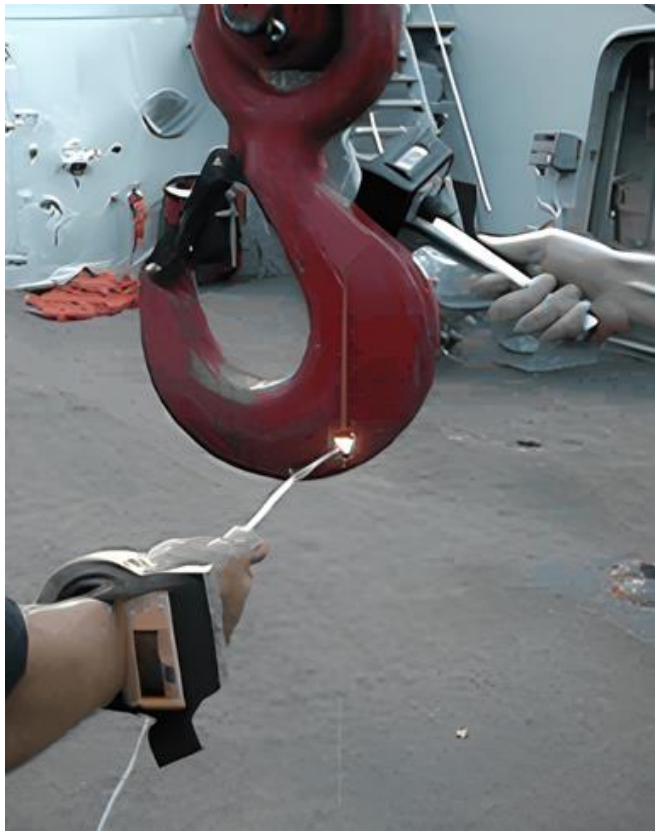
- Image shows RF-induced arcing between a rocket housing and its launcher during Hazards of Electromagnetic Radiation to Ordnance (HERO) testing.
- During HERO testing the induced current, due to RF radiation, is measured in installed, instrumented EEDs.
- HERO test configurations should include EO handling equipment e.g. loading trolleys, ammunition lift trucks etc.

Reference: *MIL-HDBK-240A, HERO Test Guide of 10 March 2011*

Arcing on loading deck of USS San Antonio Landing Platform Dock (LPD)-17

HF whip & crane cable

Experimental setup



Arcing from the crane's hook

References: *T. Keys, Radiation Hazards (RADHAZ) Presentation, Joint Spectrum Center, E3 & Spectrum Engineering Division, OS35, Defence Information Systems Agency of 13 Jan 23*
Robert Bozarth, HERO Overview, NSWCDD Q52 Electromagnetic & Sensor Systems Department, not dated, [Approved for Public Release; Unlimited Distribution]

Maximum Extractable Power

$$P_{max} = 702\left(\frac{E}{f}\right)^2\left(\frac{p}{\lambda}\right)^{3.5} \text{ for } \frac{p}{\lambda} < 0.4$$

or

$$P_{max} = 28.4\left(\frac{E}{f}\right)^2 \text{ for } \frac{p}{\lambda} \geq 0.4$$

$$f \leq 30\ MHz$$

f *is the frequency in MHz*

P_{max} *is the extractable power in W*

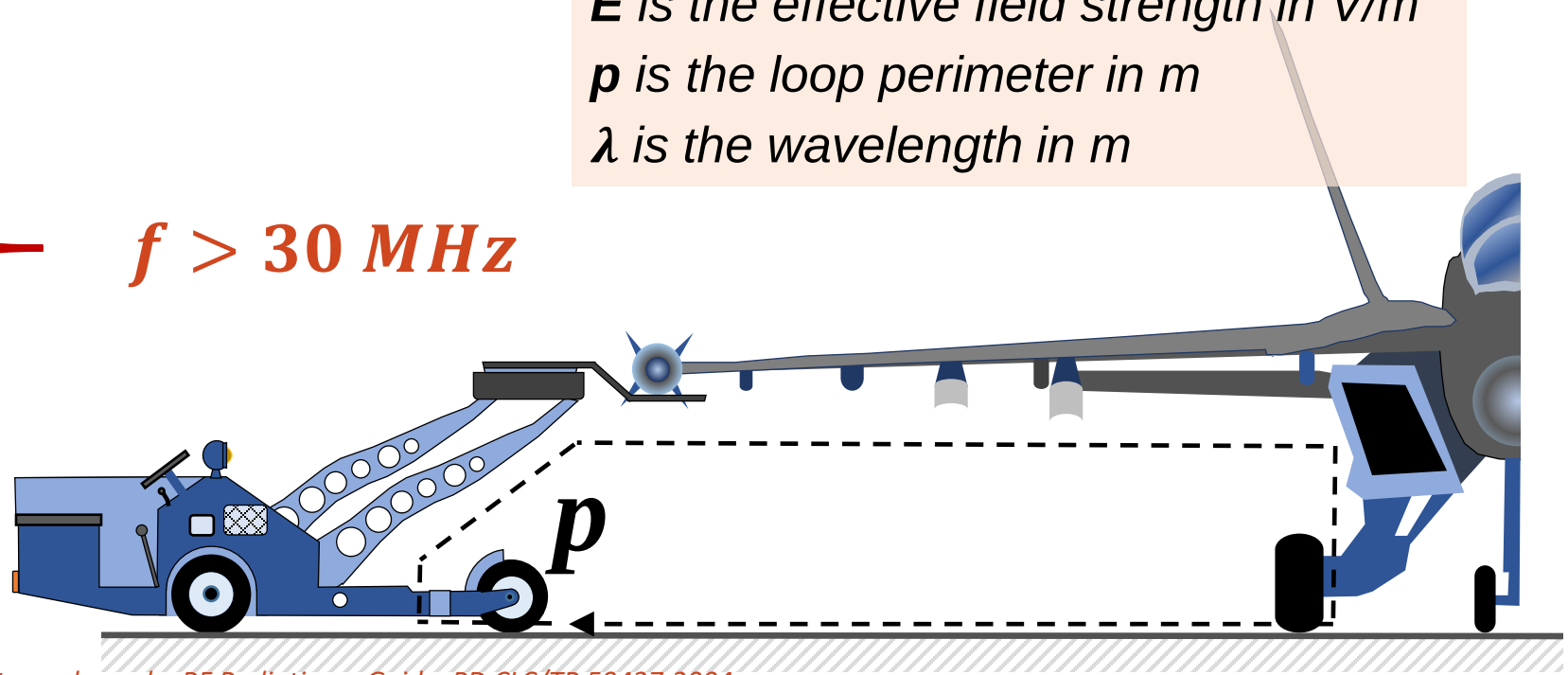
E *is the effective field strength in V/m*

p *is the loop perimeter in m*

λ *is the wavelength in m*

$$P_{max} = \frac{124E^2}{f^2 + 3030}$$

$$f > 30\ MHz$$



Reference: *Assessment of Inadvertent Ignition of Flammable Atmospheres by RF Radiation – Guide, PD CLC/TR 50427:2004*

Hazard Control Measures (Not ADF-specific)

- *"Prior to work near transmitter towers where an electrical charge can be induced in the equipment or materials being handled, the transmitter shall be de-energized or tests shall be made to determine if electrical charge is induced on the crane."*
- *"Ground jumper cables shall be attached to materials being handled by boom equipment when electrical charge is induced while working near energized transmitters."*
- "*Crews shall be provided with non-conductive poles having large alligator clips or other similar protection to attach the ground cable above the load.*"

Reference: US Occupational Safety and Health Administration (OSHA) Standard 29 CFR §1926.550 (a) (15) (vii), Cranes and Derricks

Other Hazard Control Measures (not ADF-specific)

- Insulating links preclude a hazardous voltage from being present on the hook itself.
- Does nothing with regards to hazardous voltages above the insulator.

- Smart, load-bearing insulator shown.
- 25kV rated operating voltage and weight rating up to 120 ton (for *Insulatus* P/N 120TV2).
- The insulator features on-board diagnostics e.g. self-test, data logging and a warning alert.

Reference: *Insulatus Insulating Lift Technology Product Brochure of 2018* https://www.insulatus.com/products/load-insulator/

Other Hazard Control Measures (Not ADF-specific)

- Non-metallic materials will not be susceptible to RF induced currents.
- *Dyneema*® crane ropes, as example, are made using ultra-high-molecular-weight polyethylene (UHMWPE) and find use as load lines in mobile, tower and overhead cranes.

- Dielectric strength of 900 kV/cm and is quoted to be ‘highly transparent’ to radars.
- The *HPME/Dyneema*® ropes *“…have such high strength performance, that they are replacing steel wire and chains for heavy lifting operations both on- and offshore.”*

Reference: *https://dynamica-ropes.com/dyneema-ropes/*

Hazard Control Measures, RAN-specific

- During *Crane Ops*, Hazards of Electromagnetic Radiation to Personnel (HERP) is arguably the main focus of hazard controls measures.
- Prevents personnel from being exposed to excessive RF radiation and ‘energised’ RF cables.
- HERP control measures may be effective for HERO (in given context).
- Examples of hazard control measures include:
  - maintaining appropriate Safe Separation Distances to cater for HERP (and HERO);
  - seeking approval to raise any structure (e.g. ‘cherry’ picker or scissor lift) adjacent to, or on the ship due to the potential for RF re-radiation;
  - ceasing RF emissions during ammunitioning activities;
  - using admin controls to track Safe To Transmit (STT) key switches;
  - ceasing *Crane Ops* if required;

Hazard Control Measures, RAAF-specific

- RAAF Base Maps used for planning purposes to determine where fixed RF emitters may be installed and operated.
- Fixed, high-power, RF emitters on a RAAF Base will be well-separated from any Ordnance Loading Areas (OLAs).
- SSDs for low-power RF emitters maintained via the use of EO-specific Topic -027 publications.

- Topic - 027 publications may highlight special considerations for the use of EO handling equipment e.g. ammunition loaders, lift trucks etc.
- Cognisance concerning high power RF emitters that may be located outside the boundaries of the Base.

Hazard Control Measures, Army-specific

- RADHAZ surveys used to quantify the Electromagnetic Environment (EME) around vehicles and identify E-field hot spots.
- RADHAZ survey data used for HERP and HERO assessments.
- Use of Emission Controls (EMCON) e.g. during EO (un)loading operations.
- Topic -027 publications may highlight special considerations for the use of certain mobile cranes or platform-mounted cranes.

RADHAZ survey on HX-77 Truck

Note: Simple current probe can be used to detect induced currents in crane cables.

Conclusion

Double Eagle ROV deployed with mine disposal charge.

- LTSs are used across the ADF for different EO handling operations.
- LTSs may form efficient antennas, especially for frequencies up to 30MHz.
- Extant HERO and HERP controls are generally effective to mitigate the hazards associated with induced currents and voltages on LTSs.
- Scope of RADHAZ surveys to be expanded to measure induced currents in LTSs.
- Hazards remain for RF emitters not previously considered e.g. at new ammunitioning ports.
- Awareness about the hazard and effective control thereof - essential to ADF's interoperability objective.

Questions?

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