Introduction to Directed Energy

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References

Outline

• DE Intro
• EW vs. DEW
• High Energy Laser
• High Power Microwave Weapon
• HPM weapon building blocks and components
• DEW system examples
• DEW countermeasures
• Summary
Directed Energy Weapon (DEW)

• DEW
  – Directed (Aim)
  – Emit highly focused energy
  – Transfer the energy to a target

• Forms of energy
  – EM radiation: RF/microwave, laser
  – Sound (sonic weapons)

• Applications
  – Military, law enforcement, commercial
  – Anti-personnel weapon system
  – Missile defense system
  – Disabling lightly armored vehicles (cars, drones)
  – Disabling electronic devices
  – Crowd/riot/prison control (non-lethal)
  – Medical/surgical
EM Weapon Advantages

- EM (RF/microwave, laser) advantages over conventional weapons
  - Speed of light (target movement)
  - Only slighted affected by gravity; Wind speed can be neglected
  - Changing focusing configuration to control active area (target)
  - No sound or light (detected by human senses)
  - With sufficient power source, essentially limitless ammunition
Electronic Warfare and Directed Energy Weapons

• Electronic Warfare (EW): Use of electromagnetic and directed energy to control the EM spectrum or attack enemy
  – Electronic Attack: Attack personnel, facilities, or equipment; Degrading, neutralizing, or destroying enemy combat capability
    • Temporary "upsets" in electronics subsystems
    • Permanent circuit deterioration
    • Permanent destruction due to burnout or electrical overload
  – Electronic Support: Search, intercept, identify, and locate sources of radiated EM energy for threat recognition
  – Electronic Protection: Protect personnel, facilities, or equipment for any effects of friendly or enemy employment of EW

• EW and DE: Technologies for non-lethal (no permanent injury) or less than lethal (could suffer serious injury) forces
EW Jammer vs. DEW Power [1]

Tactical High Energy Laser (THEL) [4]

• Laser Subsystem (LS)
  – High power chemical gas laser

• Pointer Tracker Subsystem (PTS)
  – Beam Director Assembly (BDA)
    • Accepts the beam generated by the laser, performs beam focusing functions, and slews to follow threat targets
  – Beam Alignment and Stabilization Assembly (BASA)
    • Performs alignment and stabilization functions on the focused laser beam
  – Off-Axis Tracker (OAT)
    • A low resolution infrared tracker with a wide field-of-view for initial acquisition of targets
  – Shared Aperture Tracker (SAT)
    • A high resolution short-wave infrared tracker with a narrow field-of-view for target tracking
  – PTS Controller (PTSC)
    • Accepts commands from the SAT, OAT, and C3I subsystems to point the BDA at the target

• Command, Control, Communications, and Intelligence (C3I) Subsystem (including fire control radar (FCR))
  – Controls all THEL system operations. Target search, detection, classification, track-while- scan, and handover
THEL Target Engagement Sequence

Reference [4]

http://www.dsiac.org/resources/journals/taxonomy/WSTIAC/all
High Power Microwave Weapon [5]

- High Energy Laser (HEL) weapons: Use beams of EM radiation with wavelengths usually in the infrared
- **High Power Microwave** (HPM) weapons: Radiate EM energy in the high RF spectrum
- Charged particle beam (CPB) weapons: Project energetic charged atomic or sub-atomic particles, usually electrons
HPM Parameters

- Peak power $\geq 100$ MW
- Pulsed energy $\geq 1$ joule per pulse
- Frequency band and bandwidth
  - NB: 1 to 35 GHz, BW < 10% of center frequency
  - WB: 0.01 to 2 GHz, BW > 10% of mean frequency
  - UWB: 0.01 to 2 GHz, BW > 25% mean frequency
- WB/UWB: Not necessary to know the optimum frequency to attack; Power at any given frequency is usually very small
- NB: Much more efficient if a narrow optimum frequency range is known (frequency couple to target)

Reference [5]
## DEW vs. EW Effects

<table>
<thead>
<tr>
<th></th>
<th>EW</th>
<th>DEW</th>
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<tbody>
<tr>
<td>Effects after system turned off</td>
<td>Do not persist</td>
<td>Persist</td>
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<tr>
<td>Target system features</td>
<td>“In-band”</td>
<td>“In-band” or “out-of-band”</td>
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<td>Power level</td>
<td>Low</td>
<td>High</td>
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<td>Target impact</td>
<td>Target specific</td>
<td>Less target specific</td>
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<td>Target intelligence information</td>
<td>Require details</td>
<td>Require less</td>
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</tbody>
</table>
Target Susceptibility Values: Decreasing

Reference [5]
Target Effects: Characterization

- Probability of target failure curves
- Footprint
- “Time-on-target”: Lethal/nonlethal can depend on “on-time”

Reference [5]
# DEW Target Effects

<table>
<thead>
<tr>
<th>DE source</th>
<th>HPM</th>
<th>HEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>0.1 cm – 3 m</td>
<td>0.27 μm – 10 μm</td>
</tr>
<tr>
<td>Energy coupling</td>
<td>Internal electronic components</td>
<td>External materials</td>
</tr>
<tr>
<td>Lethality</td>
<td>Electronic upset, burn out</td>
<td>Thermo-mechanical structural damage</td>
</tr>
<tr>
<td>Typical targets</td>
<td>Missiles Electronics</td>
<td>Missiles Satellites</td>
</tr>
<tr>
<td>Typical range</td>
<td>100s m – 100s km</td>
<td>Few km – 1000s km</td>
</tr>
</tbody>
</table>
HPM Lethality Methodology

Reference [5]
HPM Weapon Building Blocks

Reference [5]
HPM Weapon Components

Reference [5]
HPM Weapon Antenna Configuration

HPM System Component R&D
ARL Antenna Research
Folded Path Antenna

1. Feed & field shaping interface
2. Trans reflector
3. Twist reflector

Reference [5]
Desirable Features for HPM Source

• Frequency tunability
  – Maximizes flexibility, hard to protect against

• High efficiency
  – Minimizes prime power and cooling requirements

• Minimal external component requirements (e.g., cooling, magnetics)
  – Minimizes system weight and volume

• Ability to accommodate complex RF modulations
  – Increases probability of effect at lower power or longer range (but requires more detailed knowledge of target)

• High peak or average power (depends on target susceptibility and operational scenario)
  – Increases probability of effect

• Repeatable
  – Longer target exposure, higher total energy delivered to target
System Examples

• Active Denial System
  – Millimeter wave source (95 GHz, 3.2 mm wavelength)
  – Heats the water in the target’s skin and thus causes incapacitating pain
  – Riot control
  – Can also destroy unshielded electronics
  – Raytheon
System Examples

• Vigilant Eagle
  – Airport defense system
  – Directs high-frequency microwaves towards any projectile that is fired at an aircraft.
  – Consists of a missile-detecting and tracking subsystem (MDT), a command and control system, and a scanning array.
  – The scanning array projects microwaves to disrupt the surface-to-air missile’s guidance system.
System Examples

• Bofors HPM Blackout
  – High-powered microwave weapon system
  – Destroy at distance a wide variety of commercial off-the-shelf (COTS) electronic equipment.
  – Not lethal to humans
  – BAE
System Examples

• EL/M-2080 Green Pine radar
  – Its effective radiated power (ERP) makes it a possible candidate for conversion into DEW
    • Focusing pulses of radar energy on target missiles
  – The energy spikes are tailored to enter missiles through antennas or sensor apertures to
    • Fool guidance systems,
    • Scramble computer memories
    • Burnout sensitive electronic components

– Specifications
  • L Band (500 MHz to 1000 MHz, or 1000 MHz to 2000 MHz)
  • Range 500 KM (310 mi)
  • Precision ±4 m (13 ft)
  • Diameter 9 m x 3 m
DEW Countermeasures

• HEL DEW
  – Spectral filters
  – Ablative coatings (absorb heat; protect metal substrate underneath)

• HPM DEW
  – In-band limiters, filters
  – Out-of-band EM shielding

• Assessment of DEW effect
Summary

• EW vs. DEW
• High Energy Laser vs. HPM Weapon
• Countermeasures (part of electronics design)
• DEW design requirements
  – DEW systems: Compact, mobile, efficient, reliable, maintainable and affordable
  – DEW target effects: Consistent and predictable
  – Effect level: Lethal to nonlethal
• Challenges
  – Compact, high peak power and/or high average power HPM sources
  – Compact, high gain, NB and UWB antennas
  – Compact, efficient, high power, pulse power drivers
  – Predictive models for HPM effects and lethality