Next Generation Adaptable RF Seekers for Precision Munitions

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Dr. Cory Myers
BAE Systems IEWS
cory.s.myers@baesystems.com
Mission Need

- Provide small unit of operations with organic Precision Strike capability against High Value Targets
- Accelerate Enemy Defeat
- Reduce Collateral Damage
- Improve Deployability & Logistics
- RF Guided Munition (RFGM)
  - Provide a low cost precision means for ground forces to engage C3 targets, enemy FOs, and some radars
  - Completes the sensor-to-shooter chain for IO targets operating from 30MHz to 3GHz

**Current Mortar Munitions generally do not achieve first shot direct hit on target. RFGM guidance system capable of correcting trajectory improves first-shot hit on the target to 50%.”**
System Concept

• Exploit dismounted, close-in attack scenario with small aperture, RF seeking weapon
  – If the dismount (SOF) can be cued to the presence of the emitter then the dismount can attack the (soft target) emitter with an organic weapon (e.g. 81 mm mortar)

• Create a passive, all-weather, and inexpensive precision RF seeker capability for multiple weapon types
  – Enable a suite of precision and area suppression weapons (ground-to-ground, ground-to-air, and air-to-ground) that home on RF energy all using similar RF seeker and guidance technology

• Deny enemy use of RF spectrum for military purposes
  – Counter enemy radar/IR/acoustic signals Camouflage, Concealment and Deception (CCD) efforts
Technical Challenges

System Requirements:
- **Quick**: Geo-location estimate must be fast enough (5 sec) to guide a mortar which has only 25-30 seconds of flight time
- **Precise**: Geo-location with an objective radius of an 81 mm mortar (20 m)
- **RF Emitters**: Target frequencies from 30 MHz to 3 GHz and multiple waveforms
- **Single**: Emissions received by only a single platform (passive technique)
- **High-Velocity**: Velocity of a mortar varies from 300 m/sec to 100 m/sec
- **Small**: e.g. 81 mm mortar form factor restricts antenna size and distance

Technology Enablers:
- Organic detection (cueing) capability
- Small, lightweight, wideband, and inexpensive RF receivers
- Inexpensive memory and processors
- Proliferation of guided weapons (IR, laser, GPS, etc.)
DARPA RFGM Program

- Replacement fuze/guidance package that effectively converts current, ballistic 81 mm mortar munitions into precision RF guided munitions
- Screw-on mod-kit
- Affordable, Easy to use
- Frequency range 30MHz to 3GHz
- Accuracy not dependent on visual observation
- Fire and Forget
- Passive, all-weather
- Technology that is scalable to other munitions
System Operation

Launch Cue → Geo-locate → Maneuver toward target → Detonation

Initial detection, discrimination, and Geo-location to <1.5km radius circle

<20m accuracy (CEP) with << 0.3\lambda aperture

Maneuver capability and stable control

3m Airburst using GOTS proximity fuze

System Integration

• Miniaturize to a 81mm mortar round
• Cost effective
• Match maneuver, target, and munitions capability

Existing technology Extension of existing technology Seedling analysis indicates feasible

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Design/Trade Space

• Cueing:
  – The weapon receives cueing information from an external system such as Wolfpack, ACS, etc.
    • Utilize SIGINT standard emitter descriptors (carrier frequency, bandwidth, modulation, etc.)
      to future proof weapon versus template matching emitter waveforms
• Geo-location
  – Despite high SNR condition, classic DF techniques alone will not work well enough
data due to the limited aperture size/spacing and the (low) frequency range of interest
• Maneuver toward target
  – Guidance/control techniques are well known (e.g. ERGM, PGMM, etc.)
• Detonation
  – Utilize existing GOTS fuze technology to avoid re-qualification costs
• System Integration
  – Optimizing the relationship between geo-location accuracy and aerodynamic control authority while minimizing weight, volume, and cost and impact on weapon range and effects
    • Integrating the RF Guided Munition kit with the fuze is preferred
    • Volume/length will need to be added to the weapon (mortar) for antennas, RF electronics, signal processing, and control surfaces in a manner that minimizes range loss
    • Using GPS is possible but an IMU may be sufficiently capable while being cheaper than SASSM modules – both add a precise targeting capability
RF Guided Munitions Program

**Phase 1:**
- Task 1: Core Geo-location Technologies
  - Design
    - Antenna
    - RF Hardware
    - Geo-location Signal Processing Software
  - Demo
    - Captive Carry

**Phase 2:**
- Task 1: Core Geo-location Technologies
  - Design
    - Antenna
    - RF Hardware
    - Geo-location Signal Processing Software
  - Demo
    - Captive Carry

**Phase 2 Risk Reduction**
- Emitter Discrimination
- Miniaturization
- Maneuverability
- Discriminate Target
- 81 mm Form Factor
- GNC Demo
- Soft Launch

**Phase 3:**
- Refine & Harden All Components for Operational Launch
  - Antennas
  - Electronics
  - Control Surfaces
  - Objective weapon (e.g. 81mm mortar) Form Factor Demo
  - Operational Launch

Alternate weapon platforms to the 81mm mortar will also be considered for funding if a transition sponsor has been identified.

**Go/No-Go**
- Phase 1 Go/No-Go
  - 50% geo-location estimates w/in 20m of actual emitter
- Phase 2 Go/No-Go
  - 50% geo-location estimates w/in 20m of actual emitter
- Phase 3 Go/No-Go
  - 50% Rounds impact w/in 20m of target emitter

**Final Demo and Transition**

Contract Award/Kickoff Sep/Oct 04

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Geo-location Challenge

- Geo-location Error Sources:
  - Thermal noise
  - Quantization noise
  - Phase noise
  - Receiver spurs, intermods and harmonics
  - Man-made noise and atmospheric noise at HF
  - Navigation errors from position and roll sensors
  - Channel mismatch errors
  - Calibration errors
  - Multi-path signal corruption
  - Co-channel signal interference
  - Platform motion induced modulation

- Geo-location Requirements:
  - Provide guidance commands well before apogee to support maneuver basket.
  - Deal with multi-emitter environment. Guide to one emitter, not the centroid of emitters.
  - Provide resiliency to multi-path and polarization.
Geo-location Challenge

Angular precision of classic DF techniques is limited by $\lambda/D$, SNR, and channel mismatch which is unacceptable for low frequency emitters.

Lower Frequency
- Dominated by channel mismatch which causes a biasing error

Higher Frequency
- Dominated by imprecision in guidance (GPS/IMU error)

Incapacitation:
- <50%
- 50% - 100%
- 100%
Geo-location method uses temporal, phase and amplitude information from all the antenna elements, separates signals of interest and then determines emitter geo-location metric by computing the probability likelihood surface of the potential emitter location as a function of its hypothesized location.
Model of combined geo-location and guidance shows better performance than the specified 20m CEP goal with a maneuver basket of 1.5km in radius.
System Integration

Multiple subsystems need to be integrated, in addition to geo-location, to make RFGM a reality:

- Antennas
- Receivers
- Actuators
- Wings
- Navigation
- Guidance
- Control
- Signal Processing
- Power
- Cueing
- Fuze
Questions?
Points of Contact

DARPA/ATO Program Manager
Dr. John Allen
jallen@darpa.mil

BAE Systems Program Manager
Ms. Marianne Tenore
marianne.tenore@baesystems.com
Phone: 603-885-8470

BAE Systems Management
Dr. Cory Myers
cory.s.myers@baesystems.com
Phone: 603-885-6845

BAE Systems Business Development
Mr. Daniel Bradford
daniel.bradford@baesystems.com
Phone: 603-885-5937