New Generation Naval Artillery Multi-Function Fuze

56th Annual Fuze Conference
"Next Generation Fuzing for Next Generation Weapons"

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Outline

- Proximity Fuze Technologies
- New Radar Sensor - Application to Naval Fuzes
- FMCW – Digital Signal Processing: Performances and Benefits
- New Generation Proximity Fuzes for Naval Artillery: FREMEN 100mm & FREMEN 76mm
- Fuze Main Features and Design
Company Presentation

- A leader in the field of ammunition fuzes and S&A devices
- Full range of products
- Key competences in
  - Fuzing technologies
  - Micro-technologies
  - Ammunition electronics
Proximity Fuze Background

- More accurate
- More ECM resistant
- More flexible
- More functions

CW Doppler
(CW-Continuous Wave)

Frequency Modulation
(FM-CW)

Digital Signal Processing
Spectrum Analysis

1960
1985
1995
2000
2010
2012
New Generation Proximity Sensor

- New state-of-the-art proximity sensor developed by JUNGHANS and qualified in 2007 in the FRAPPE artillery multifunction fuze
  - FM-CW Microwave Radar Sensor + Full Digital Signal Processing

Main benefits for the user
- Better detection accuracy
- Better operational flexibility (HOB setting)
- Better resistance to jamming and electromagnetic countermeasures

Then used in other fuzes
Back to Basics

- Conventional Air-Defence CW Doppler Fuze
  - $F_d = \frac{2V}{\lambda} \cdot \cos \alpha$
  - Target information provided:
    - Amplitude (radar cross section)
    - Relative target velocity (doppler)
  - Main issue: separation of target and clutter, in particular for very low altitude target (sea skimming missile, helicopter, drones)

- FM-CW Radar Sensor Principle
  - $F_b = \frac{2D}{c} \cdot \frac{\Delta F}{T}$
  - $F_b$ is proportional to the target distance $D$
  - Target information provided:
    - Amplitude (radar cross section)
    - Relative target velocity (doppler)
    - Target distance

FMCW sensor provides a key information on the target: its DISTANCE
Main Objective: Improve air-target detection performances
- Increase the ability to detect a flying target in difficult conditions, in particular with stormy sea conditions (e.g. sea skimming missile)
- Reduce the false alarm rate (early burst)
- Enhance the resistance to electromagnetic disturbances and countermeasures
- Improve the capability to attack surface targets (sea and land)

Solution:
- Use the new generation FMCW radar sensor technique together with appropriate digital signal processing

Main challenges: Overcome specific aerial target configurations
- Very low target Radar Cross Section
- Very high interception speed
- Sea clutter disturbance
Target / Clutter Discrimination

- FMCW + Spectrum Analysis

→ Processing of the different target echo ranges
  - Allows discrimination between reflected signals:
    Range gated processing to isolate sea-clutter from valid targets
Signal Processing for Air-target detection

- Spectrum Analysis: Extraction of the target parameters
  - Target distance information
  - Speed - from the Doppler frequency shift
  - Radar cross section - from the signal level
Sea-Skimmer Detection

- Surface echoes
- Missile target echo
- Target level / Distance
- Fuze - target
- Actual trajectory and target recorded signals
Sea-Skimmer Detection

Missile target echo

Target level / Distance Fuze - target

Time / Trajectory
The Signal Processing is able to extract the target echo from the sea clutter, even in the worst conditions with a very strong sea clutter.

Signals recorded from actual firings on a very low altitude target (fixed) in presence of surface clutter, simulated by a large surface of wavy metal sheets.
Based on the new generation radar sensor fitted with smart signal processing

- To provide the user with state-of-the-art multirole fuzes, specifically designed for the optimization of terminal effect against both air and surface targets

- To achieve a broad range of missions
  - Air defence
  - Surface warfare
  - Naval Fire Support

To succeed the previous generations of naval proximity / multirole fuzes, provided by JUNGHANS, in various calibers from 76mm to 127mm
In early 2011 and 2012, JUNGHANS was awarded by the French Navy and MoD (DGA) 2 major contracts for the full development and production of new generation multirole fuzes

- **100mm** caliber: to replace the former generation fuze delivered in early 90's, with additional performances
  - for use with 100mm gun used on French Navy frigates

- **76mm** caliber: to fit new generation DIEHL Defence 76mm IM round (contract together for new round and fuze)
  - for use with the Oto Melara Super Rapido gun fitted on new French Navy FREMM and Horizon frigates
FREMEN Fuze – Main Features

- Operating modes
  - Proximity, against air or surface target
  - Impact back-up
  - Self-destruct mode, with possible inhibition
    - Manually, by external switch (100mm)
    - Automatically, through the gun setting device (76mm)

- Proximity mode
  - The fuze autonomously selects either air-defence or surface fire mode, depending on whether the sensor identifies an air or surface target

- Air target
  - Optimized to defeat various types of targets: sea-skimming missiles, small targets such as drones, fixed or low speed targets such as helicopters or drones
    - Speed from 0 to mach 2
    - Low altitude (from 4m above the surface) or high altitude

- Surface target
  - Land or sea targets
FREMEN Fuze – Design Overview

- Antenna and microwave circuit
- Sensor Electronic Module Incl. Battery
- Lithium Reserve Battery
- Mission Management Electronic Module
- S&A Device
- IM Booster

Modular Design

FREMEN 100
FREMEN 76

A Diehl and Thales Company
FREMEN Fuzes - Programme Status

- **FREMEN 100mm and FREMEN 76mm**
  - Contracts awarded in 2011
  - Definition Phase in progress
  - Sensor tests carried out on various types of targets, incl. small targets
  - FREMEN 76 development carried out at the same time as the FREMEN 100 development
  - LRIP delivery: 2014

FMCW sensor expected performance validated through live target firings (Fuzes specially equipped with embedded data recorders and telemetry)
Summary

- Up to now, FMCW + Digital Signal Processing techniques have not been implemented in Naval Artillery proximity fuzes (air defence)
  - This technology will considerably improve the proximity fuze efficiency and reliability, in particular by its capability to discern more easily the target signal from the sea clutter
  - JUNGHANS has successfully demonstrated the possibility to integrate this technology in new generation naval artillery proximity and multifunction fuzes

With the new generation FREMEN fuzes, JUNGHANS will provide the Navy with unmatched operational capabilities to defeat air targets as well as surface targets, on land or sea.
Thank You

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