An Approach to Addressing Spectrum Management Issues for Radar Systems

TC-6 Spectrum Management Meeting
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Outline

- Introduction
- Past Problems / Issues and Responses
- Current Issues
- Recommendations for the Future
- Summary

Past Problems – RFI/EMI

- Some DoD Examples
  - USS Forrestal (CV-59)
  - USS Enterprise (CV-65)
  - HMS Sheffield (D-80)
  - US Army Blackhawk Helicopter

Past Problems – USS Forrestal

- USS Forrestal (CV-59)
- Explosion on deck 29 July 1967
- Caused by the “self-firing” of a Zuni missile
- 134 Dead, 161 injured, 21 aircraft stricken from inventory
- Required almost 7 months for repairs.
- Cost to US Navy - $72 Million

USS Forrestal

Crew members fighting fires on board *Forrestal.*

USS Forrestal

Crewmembers in front of what remains of a row of F-4B Phantoms that were parked along the starboard stern quarter

Past Problems – USS Enterprise

- USS Enterprise (CV-65)
- Explosion on deck 14 January 1969
- Caused by the “self-firing” of a Zuni missile
- 27 Dead, 314 injured, 15 aircraft destroyed
- Required 3 months for repairs, primarily to flight deck armor plating

USS Enterprise

Enterprise fire, 14 January1969

USS Enterprise

Enterprise fire, 14 January1969

Past Problems – HMS Sheffield

- HMS Sheffield (D-80)
- Deployed to the South Atlantic during the Falklands War
- Attacked 4 May 1982
- Hit by Exocet missile, fired by an Argentine aircraft
- 20 Dead and 24 seriously injured due to attack
- Hull had holes in multiple places
- Sunk on 10 May 1982 while under tow

HMS Sheffield

- HMS *Glasgow*, Sheffield's sister ship, detected Argentine jets inbound to fleet. *Glasgow*'s electronic warfare support measures (ESM) equipment detected the Exocet's "seeker" radar, which meant that an incoming missile or missiles were headed for the ships.

- *Glasgow* radioed the news to the anti-air warfare coordinator on board the carrier *Invincible* but, unfortunately, the coordinator dismissed the report as one of the **many false missile attack alarms** received that same morning.

HMS Sheffield

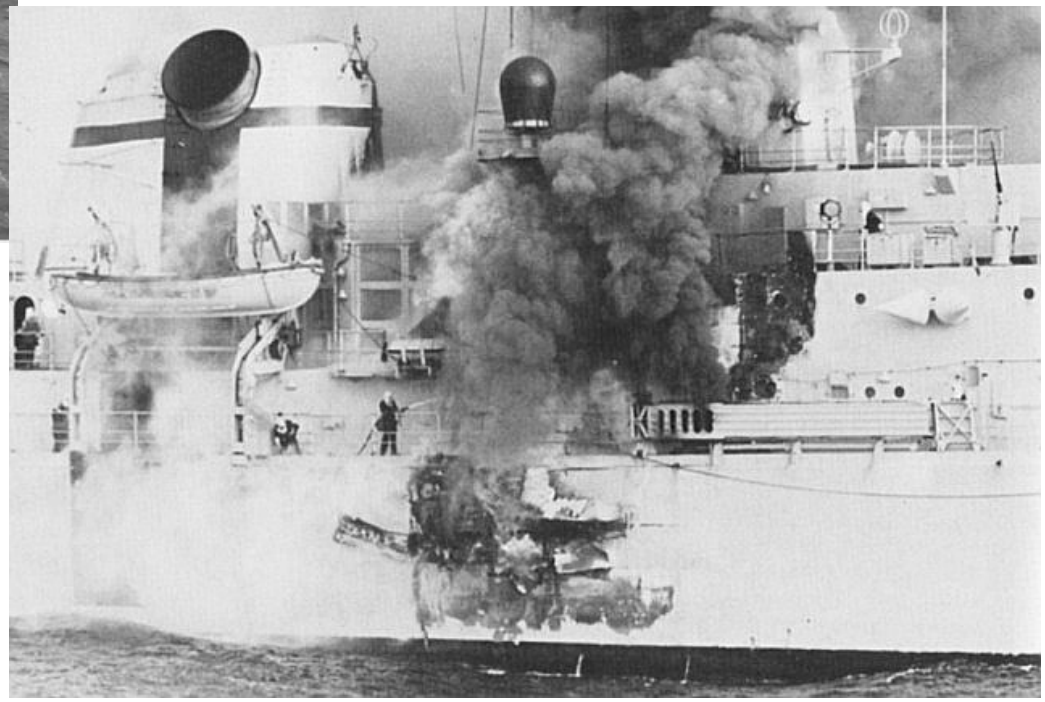
- Meanwhile, *Sheffield*'s radar did not pick up either the incoming planes or missiles because, at that precise moment, her satellite communications terminal was in use and that prevented the onboard ESM equipment from operating. The **satellite communications link, therefore, proved incompatible with the ship's anti-missile radar**, although neither the Type 965 radar or the Sea Dart missiles carried by *Sheffield* were really designed to intercept low-flying cruise missiles.

- By the time *Sheffield* received *Glasgow*'s radioed warnings, the missiles could literally be seen heading towards the ship. A few seconds later, one of the Exocets hit *Sheffield* directly amidships.

HMS Sheffield

Type 42 Guided Missile Destroyer

HMS Sheffield



Type 42 Guided Missile Destroyer

HMS Sheffield

Past Problems

- US Army Blackhawk Helicopter
- The Army grounded all UH-60s 1986 after one crashed near a high-powered citizens' band transmitter in Alabama, killing all three servicemen aboard.
- But Army aviation officials ordered the copters back in the air 49 days later without telling pilots -- or the Army's top general -- that the service's safety experts believed there was a 50 percent chance of a similar accident within a year.

http://catless.ncl.ac.uk/Risks/5.56.html

Past Problems

- In five accidents, the Black Hawks were flying below 1,000 feet when they suddenly dove straight into the ground, killing everyone aboard. While the Army listed mechanical causes for three of the crashes, senior Army investigators say they believe radio waves, called electro-magnetic interference (EMI), were the real culprits. The other two crashes are officially unsolved, although investigators suspect EMI.
- While the Army minimizes the Black Hawk's vulnerability to radio waves, the Navy, which also uses the aircraft, has taken a far different approach. The Navy barred its first 14 Black Hawks -- bought for training purposes in 1982 -- from coming within "a significant number of miles" of radio towers for fear of accidents, a senior Navy engineer said. The Navy later demanded that its future Black Hawks, known as Sea Hawks, be heavily shielded from electronic interference. They can now buzz radio towers with impunity.

http://catless.ncl.ac.uk/Risks/5.56.html

UH-60 Blackhawk

Commercial Problems Still Abound

- **1993 - FAA Regulates the Use of Portable Electronics on Aircraft**
  - In response to numerous reported instances of laptop computers and other electronic devices interfering with commercial aircraft systems, the U.S. Federal Aviation Administration issued AC 91.21-1, "Use of Portable Electronic Devices Aboard Aircraft," which restricts the use of cell phones and other portable electronic devices on aircraft.

- **1994 - FDA Advises Wheelchair Manufacturers to Warn Users about Interference from Cell Phones**
  - In response to reports of electric wheelchairs that spontaneously engaged as a result of interference from cell phones or other sources, the U.S. Food and Drug Administration issued an advisory recommending that wheelchair manufacturers improve shielding and add warnings to their products.

Commercial Problems Still Abound

- **1995 - FDA Issues Advisory Concerning Cell Phone Interference with Cardiac Pacemakers**
  - In response to laboratory studies showing the potential of cell phones to interfere with the normal operation of pacemakers, the U.S. Food and Drug Administration issued an advisory recommending that pacemaker wearers not carry cell phones in their shirt pockets.

- **2007 - Report Documents Cell Phone Interference with Medical Equipment**
  - University of Amsterdam researchers recorded nearly 50 incidents of electromagnetic interference from cell phone use in hospitals and classified 75 percent of them as significant or hazardous.

- **2008 - Study Links RFID Devices to Interference with Medical Equipment**
  - Another University of Amsterdam study investigated the potential of RFID devices commonly found in hospitals to interfere with medical equipment.

Current Issues – Spectrum Management

- DoD used to be the “Spectrum King”, but is now one of many players in the court
  - Spectrum Loss
  - Spectrum Incursion
  - Spectrum Sharing
- Can we develop, define and articulate design approaches that deal with decreasing spectrum availability and sharing?

Current Issues – Radar

- New Sources of Interference to Radars
  - Wireless / WiMax systems
  - Tailored waveforms and coding approaches
  - Windmill Interference
- Develop radar design approaches that incorporate “spectrum robustness”
  - Cognitive Radar
  - Adaptive Radar

Current Issues – Communication

- Many competing (and Interfering) services
  - Radar / Communications / Wireless / WiMax
- We need to reconcile and validate the various documents and procedures that affect “radiating systems” – Red Book, RSEC, etc.
- We need to develop and validate design and spectrum management approaches that look at “radiating systems” and how to incorporate new technologies and issues.
  - Use general approaches, then specialize to particular applications

Recommendations for the Future

- Education
- Data Collection
- Data Organization
- Develop Appropriate IEEE Standards / Recommended Practices
- Funding

Recommendations - Education

- In the “good ol’ days” most radars were primarily RF devices
  - Early processing was done by screen phosphors and the Mark I eyeball
  - Radars used relatively simple waveforms
  - Radars performed fewer functions
  - Radars were more easily placed to avoid interference with others
  - The RF environment was fairly straightforward (AM, FM, SSB)
  - The RF environment was much less crowded

Recommendations - Education

- Today, radars are sophisticated computers with an RF front end
  - Very sophisticated processing of radar signals
  - There are a multitude of radar waveforms, with very sophisticated coding
  - Radars perform many more functions
  - Many more types of radar (UWB, Noise, “through the wall”, etc.) both military and civilian
  - RF environment contains many complex waveforms
  - Spectrum is much more crowded and getting worse

Recommendations - Education

- In the “good ol’ days” many people in the regulatory agencies were engineers and/or had hands on experience with using the spectrum (broadcast engineers, amateur radio operators)
- Many good people are in place, but too few appreciate that in the end physics determines how waves propagate, not policies and procedures
- Various radars operate in their portions of the spectrum to accomplish specific tasks and can not be arbitrarily moved around in the spectrum

Recommendations - Data Collection

- Currently, we are too often operating from anecdotal information
- We need real data to make real decisions that can be developed and defended
- There needs to be a more coordinated, better organized data collection effort
- NRL is carrying out activities in this area, but more needs to be done across the government and the services

Recommendations - Data Collection

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- Without good data, you don't know **<u>why</u>** you should follow a particular course of action

Recommendations - Data Organization

- Once data is collected, what do we do with it?
- That is, how do we collect, organize and store data so it can be readily accessed – used and not abused?
- We need both narrative information as well as data (numbers) suitable for developing policies and procedures.
- Fortunately, we have a few guide posts available to us.

Recommendations - Data Organization

- For EMI/RFI issues, there are many “data” collections, but most still of an anecdotal nature
  - Radiocommunications Agency EMC Awareness:http://www.emcuk.co.uk/awareness/Index.htm
  - The Risks Digest: http://catless.ncl.ac.uk/Risks
  - FCC Enforcement Bureau Interference Complaints: http://www.fcc.gov/eb/interference/
- What is really needed is a data base that combines narrative with numbers

Recommendations - Data Organization

- Fortunately, there is an excellent “template” that can be used:
  - Aviation Safety Reporting System
  - http://asrs.arc.nasa.gov/
  - Incidents can be reported anonymously
  - Database is structured to collect all the data needed to make safety related decisions and recommendations

ASRS Fields

ASRS Coding Form Fields	ASRS Database Online Report Display Fields	ASRS Database Online Search Fields	Field Type
ACN	ACN	Report Number (ACN) was [number]	Number
TIME			
Date	Date	Date of Incident was between [date] and [date]	Fixed
Day	Day		Fixed
Local Time of Day	Date		Fixed
PLACE			
Locale Reference	Locale	Location was [identifier]	Fixed
State Reference	State Reference	State was [abbreviation]	Fixed
Relative Position			Fixed
Altitude	Altitude		Fixed
ENVIRONMENT			
Flight Conditions	Flight Conditions	Flight Conditions were [conditions]	Fixed
Weather Elements	Weather Elements	Weather Elements were [weather]	Fixed
Light	Light	Light Conditions were [conditions]	Fixed
Ceiling			Fixed
Visibility			Fixed
RVR			Fixed

ASRS Fields

AIRCRAFT X			
Reference			Fixed
Controlling Facilities	Controlling Facilities		Fixed
Coordinating Facilities			Fixed
Operator	Operator	Operator was [organization]	Fixed
Crew Size			Fixed
Operating Under FAR Part	Operating Under FAR Part	Federal Aviation Regs (FAR) Part was [regulation]	Fixed
Flight Plan		Flight Plan was [type]	Fixed
Mission			Fixed
Navigation in Use	Navigation In Use		Fixed
Flight Phase	Flight Phase	Flight Phase was [phase]	Fixed
Route in Use	Route In Use		Fixed
Airspace Occupied			Fixed
Maintenance Status			Fixed
Cabin Activity			Fixed
Cabin Lighting			Fixed
Available Seats			Fixed
Passengers On Board			Fixed

ASRS Fields

COMPONENT			
Aircraft Component (ASRS Code)	Aircraft Component		Fixed
ATA Code			Fixed
Manufacturer			Fixed
Aircraft Reference			Fixed
Problem			Fixed

PERSON X			
Reference			Fixed
Involvement			Fixed
Location of Person			Fixed
Affiliation	Affiliation	Reporter Affiliation was [organization]	Fixed
Function	Function	Reporter Function was [position]	Fixed
Qualification	Qualification		Fixed
Experience	Experience		Fixed
ASRS Report	ASRS Report		Fixed
Analyst Callback			Fixed

ASRS Fields

EVENTS			
Type of Event			Fixed
Anomaly	Anomaly	Event Type was [anomaly]	Fixed
Independent Detector	Independent Detector	Detector was [equipment/human]	Fixed
Resolutory Action	Resolutory Action	Resolutory Action was [action/inaction]	Fixed
Consequence	Consequence		Fixed
Miss Distance	Miss Distance		Fixed
SITUATIONS			
ATC Facility	ATC Facility		Fixed
Airport	Airport		Fixed
Navigational Aid	Navigational Aid		Fixed
Airspace Structure	Airspace Structure		Fixed
Aircraft			Fixed
Chart	Chart		Fixed
Publication	Publication		Fixed
Other			Fixed
MAINTENANCE FACTORS			
Maintenance	Maintenance		Fixed

ASRS Fields

ASSESSMENTS			
Problem Areas	Problem Areas		Fixed
Primary Problem	Primary Problem	Primary Problem was [cause]	Fixed
Air Traffic Incident	Air Traffic Incident	Air Traffic Incident was [type]	Fixed
NARRATIVE			
Narrative	Narrative	Text contains [text]	Textual
SYNOPSIS			
Synopsis	Synopsis	Text contains [text]	Textual

Recommendations - Data Organization

- There are some existing databases, but they are not widely known, used or believed.
- We need to develop an ASRS equivalent system – that will be used
- Spectrum Interference Reporting System
- Use ASRS as a starting point for structure
- Substitute radar types for aircraft types, etc.
- Determine additional quantitative parameters to collect in both the time and frequency domain, such as
  - Transmitter parameters
    - Operating frequency, Power levels, Waveform parameters, Modulation type
  - “Receiver” parameters
    - Bandwidths, Amplitudes and Phases
  - Environmental parameters

Recommendations - Data Organization

- Encourage the submission of both narrative and numbers
- Leave the option for anonymous narrative, but numbers need attribution and details, so they can be verified, validated and extended.
- Most important thing is to build a database of calibrated data so the science can be done.
- This implies that test programs should include their data, as appropriate

Recommendations – IEEE Std Activity

- Take existing documents, like the RSEC or the Red Book, and convert some of them (or their content) to IEEE Standards or Recommended Practices
  - Use this as an opportunity to validate the underlying theory and technology
  - Take advantage of an existing broad based review process that incorporates academia, industry and government
  - IEEE standards/practices have more “impact” on an international basis

Recommendations – IEEE Std Activity

- Do we want to focus only on radar, or look at this in the broader “emissions” context.
- Should we be working with communications community also?

Recommendations - Funding

- What more can be said?
  - Funding is the lubrication that makes the gears go round
  - Funding determines if there is real intent for change or addressing the problem
  - There’s never enough
  - However, we are really short changing ourselves
  - Not near enough to do what needs to be done
  - Being taken “out of hide”
  - Funds should be considered to be an investment as well as prophylactic

Recommendations - Funding

- Where can more funds be found?
  - Coordinate between AFRL, ARL, NRL, DOD and other affected agencies to pool resources
  - Encourage companies to apply IR&D resources to addressing spectrum issues
- Get the Range Commander's Council more engaged
  - https://wsmrc2vger.wsmr.army.mil/rcc/index.htm
  - Spectrum issues are of great concern to T&E ranges
  - Frequency Management Group (FMG)
  - Develop tasks to be funded through the T&E's S&T funding line

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- Many issues are appearing, but there is a limited amount of data on which to base decisions
- Problems should be anticipated and data should be collected to enable decision making
- All participants in the Spectrum Management process would benefit from more education to the physics underlying policy and procedure

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- Required just as much is long term commitment to improving the process
- Investigate using the IEEE standards process and machinery to give greater impact to results

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- Remember …

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- Changing things in an established culture is like changing things in a cemetery …

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- Remember …
- Changing things in an established culture is like changing things in a cemetery …
- … you don't get a lot of help from the residents.

Summary

And it ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new. This coolness arises partly from fear of the opponents, who have the laws on their side, and partly from the incredulity of men, who do not readily believe in new things until they have had a long experience of them.

Niccolo Machiavelli

Chapter VI – The Prince