RPV PIONEER ABOARD USS IOWA,
AN EMI CASE HISTORY

by

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ABSTRACT

This paper reviews the two year history of RDT&E EMI control efforts provided by the Navy's Shipboard Electromagnetic Compatibility Improvement Program (SEMCIIP) to support introduction into the Fleet of the remotely piloted vehicle (RPV) PIONEER. The effort encompassed fifteen test events from August 1986 to March 1989 as shown in Table 1. Special EMI problems resulted from the "off-the-shelf" or non-developmental item (NDI) status of PIONEER (i.e., NON-mil-spec.). Other significant issues involved signal generation and processing, ship-system interactions and application of radar absorbing material and ship barriers for systems isolation.

Remotely piloted vehicles (RVP) offer a very cost effective solution to this rec/surv problem. They have very low radar cross section and hence are often undetectable, can have very long loiter time, can be sent into circumstances where manned aircraft would be placed at unacceptable risk, and of course are of much lower cost (both procurement and operational). The US has been investing in experimental RPVs for many years. However, after the very successful use of RPVs by the Israelis in the Bekaa Valley during their conflict with the Arabs, our interest increased dramatically. In 1984, the Naval Air System Command arranged to purchase the Israeli "MASTIFF." A Marine RPV platoon was formed at Camp LeJeune in 1984 to gain operational experience with the use of RPVs. The Navy held a "Fly-Off" at the Naval Weapons Center, China Lake California in the fall of 1985. AAI Corp won that "Fly-Off" with its candidate, PIONEER, a derivative of another Israeli RPV, the SCOUT. PIONEER's airframe design was collaborative effort of Israeli Aircraft Industries and Tadiran (called Mazlat from the Israeli acronym for RPV); the electronics package design was a collaborative effort between Maslat and AAI. An agreement was negotiated whereby AAI would be the production agent in the US. AAI delivered the first three systems early in 1986.

RPV PIONEER

PIONEER is a four hundred thirty five pound (200 kg) air vehicle, fourteen feet (4.3 meters) long, with a seventeen foot (5.2 meters) wing span. It has about a hundred pound (45kg) payload capacity and is a hybrid material platform made of fiberglass, aluminum, kevlar and fabric. It is optimized for light weight, long loiter, and low total EM visibility. Its mission is tactical reconnaissance, i.e., targeting, artillery adjustment, surveillance, communications (relay) and to complement existing INTEL/RECCE systems. PIONEER is powered by a twocycle, gasoline/oil fed engine, which displaces about seventy cubic centimeters (70cc). The engine is mounted in a "pusher" configuration. Endurance is greater than five unfriendly countries. Granada operations revealed the need for covert pre-assault and assault coverage in real time. This was found necessary to better deal with unanticipated circumstances or with rapid changes which occurred as events unfolded. In Lebanon, the New Jersey's sixteen inch guns were of limited effectiveness because of inability to provide "round spotting" and hence fire correction information. In Libya, we lacked means to quickly assess the damage inflicted. This had political as well as tactical consequences, since in the Libyan operation we had to immediately defend ourselves against the charge of inflicting unnecessary civilian collateral damage.

Background

Military operations in the third world continue to be likely events despite the on-going thaw in tensions between the major powers. Specifically, the underlying dynamics which required US military operations in places such as Granada, Lebanon and Libya may diminish, but the requirement to still be able to successfully execute such operations remains, and will likely remain, into the foreseeable future. Analysis of the operations in Granada, Lebanon and Libya have shown that there is a need for improving the way we accomplish reconnaissance and surveillance (rec/surv). Film based rec/surv is just too slow. Overhead sensors which cannot penetrate weather are of limited use, and conventional aircraft pose both political and tactical risks because of the ready availability and effectiveness of surface-to-air missiles against low-level flights and the subsequent political fall-out from having captured airman paraded through the streets of...
hours and cruise speed is about one hundred (100) knots. Range varies with configuration but generally extends over the horizon. Maximum altitude is about fifteen thousand feet (4500 meters). It has two command com-

**PIONEER UHF COMMAND LINK (BACK-UP)**

- Provides redundant command and control communications
  - 420 to 450 MHz synthesized output, 100 KHz steps
  - 50W CW/5W CW selectable power output
  - Omni directional transmit/receive
  - Synthesized receiver 420 to 450 MHz
    -- 100 KHz steps local tuning
    -- 500 KHz steps remote tuning

**TABLE 2**

**PIONEER PRIMARY COMMAND LINK**

- Direct sequence spread spectrum 37 MHz bi-phase
- Wideband (spread)/narrowband (clear) operation
- Code length: Long sequence > 8 hrs
  Short sequence ~ 100 microseconds
  (for synchronization)
- PLL transmitter, fixed frequency operation “G’’ band
- 30W, CW/5W CW output power selectable
- Transmit antennas: Directional: -34 dB Gain
  (Selectable) 6 foot CSG Dish
  2° Az x 3° El Pattern @ -3dB
  Omni: 6 dB Gain
- PLL receiver, fixed frequency
- Receive antenna assy:
  Omni/directional combined in 1 unit (switched)
  Directional: -8 dB Gain
  64° Az x 40° El Pattern @ -3dB
  Omni: -2 dB Gain
  72° Az Beamwidth

**TABLE 3**

- Communications links, a primary at C-Band and a back-up at UHF. The link is direct sequence spread spectrum. The primary link is via a partially stabilized, diplexed, lobe-on-receive-only (LORO) tracker dish antenna. It has about 34dBi gain with cosecant squared shaping.

**PROJECT QUICK-GO ON USS IOWA**

In the spring of 1986, the Navy decided to dramatically accelerate the Fleet introduction of PIONEER. Secretary Lehman instituted project QUICK GO. The goal was to install RPV PIONEER on battleships as quickly as possible. This paper discusses EMI corrective action work to support installation of PIONEER on the USS IOWA BB-61.

**PRE-PERSIAN GULF SEMCIP TESTING**

In July 1986, the Navy assembled a team to install a prototype PIONEER system on USS IOWA. Shipboard Electromagnetic Compatibility Improvement Program (SEMCIP) personnel were an integral part of this team. Over the next two and a half years SEMCIP participated in fifteen different T&E efforts on PIONEER. These involved both land-based and at-sea shipboard testing. Both developmental and corrective action testing were accomplished.

Testing was accomplished in two time frames; that which occurred before IOWA’s Persian Gulf deployment, and that which occurred after she returned. The main difference between the two time frames was that after IOWA returned, the value of PIONEER had been proven. IOWA was now determined to get the optimum value and benefit of her new-found capability.
EMI and reliability. The non-mil-spec design also resulted in corrosion being a problem in the harsh marine environment. Figure 3 shows an electrodeless nickel plated connector. It held up well until a sailor took a vise grip to it. Once the nickel was penetrated it set up a powerful battery action with the connector base metal and major corrosion soon followed.

During QUICK-GO seven PIONEERS were either damaged or destroyed. At one point, four PIONEER birds crashed in a very short time period. Although everyone on the program knew that crashes of a low cost item like PIONEER were a likely price for haste in this program (where lots of new RPV pilots were being trained), the short time frame within which the crashes occurred panicked both congress and program personnel. The program was put on a sixty day stand-down pending a review of the causes.

One of the crashes was caused by EMI from the ship's HF communication transmitters. During mission flight, the RPV is controlled by a pilot at the ground control station within the hull of the ship. However, during launch and recoveries the aircraft is controlled by a pilot (and/or a student pilot) using a portable control box while positioned either on top of turret No. 3 (the aft 16" gun mount) or at a location just aft of the Helo control station. During a landing evolution on January 10th 1987, the pilot observed multiple uncommanded transfer-of-control cycles between his box (CBX) and the student pilot box (SBX). These uncommanded cycles resulted in loss of control and caused an RPV to crash land. A subsequent investigation by SEMCIP revealed that the cables connecting the RPV remote control boxes were picking up electromagnetic energy from nearby HF communications transmitting antennas. The EMI was then coupling into the ground control station (GCS) system logic.

SEMCIP had predicted that PIONEER would experience EMI caused by Ship's HF communications. Some shipboard HF transmitters may transmit up to 1000 watts from any one of several different antennas located on the ship. A cursory examination of the hardness of PIONEER during the August 1986 test indicated that it would not effectively shield out this energy. Since typical processing speeds of today's logic families extend up to the HF communications frequency band, it is likely that, if HF communications EMI penetrates at levels exceeding logic noise immunity margins (typically 400 mv for LSTTL), EMI will result. Because of this concern, SEMCIP had attempted to check for this problem during the August and September 1986 testing. Unfortunately, no HF comm problems were uncovered. Often it takes very specific modulation on specific antennas at specific frequencies to cause this type EMI. Exhaustive tests are very time consuming and were not possible aboard IOWA due to the requirement for frequency authorization to broadcast in the open environment. (as compared to in an anechoic chamber or shielded room).

When the problem manifested itself in January 1987, SEMCIP began by examining system shielding. An examination of the cables and connectors revealed very poor shielding due to both cable and connector selection and connector assembly. The resulting EMI was measured at the input to the GCS at levels as high as 14 volts. This level exceed even the 12.75 volt test environment specified in MIL-STD-461C, an event that SEMCIP has
discovered on other ships as well. It caused malfunctions and miscues such as unexpectedly switching control of the RPV from the pilot's to the student's control box, engine cut-off indications, toggling of the auto-pilot disengage control, illumination of the launcher control lights and switching of the control GCS processor to a 'hidden' diagnostic routine. SEMCIP provided recommendations to AAI for eliminating the EMI. These included an improved cable for connecting the CBX and SBX to the GCS, improved connectors (with integral backshells), proper assembly/wiring of internal shields on cables, EMI hardening of the student's and pilot's remote control boxes, installation of low pass line filters with 20dB or greater insertion loss where the CBX/SBX cables connect to the GCS, and recommendations to harden the GCS logic by switching from a 'pull down' to a 'pull up' configuration to improve noise immunity.

Other problems investigated by SEMCIP were HF EMI to the COHU camera and to the RPV system intercommunications system (ICS) and an unknown source of EMI to the main video. The ICS is used for communications between the GCS, the portable command station (PCS) co-pilot position on the O-2 level aft of the helo control. The EMI caused medium to severe EMI to the ICS and mild to medium EMI to the COHU camera. Recommendations for corrective actions were provided to AAI personnel. These included instructions for improved cabling and shield terminations. The EMI to the video remained an elusive but nagging problem during much of our testing. It was eventually resolved via a series of changes made by AAI.

POST PERSIAN GULF SEMCIP TESTING

SEMCIP had four post-deployment concerns: locating a second tracking dish to provide for three hundred sixty (360) degree control (and hence utilization) of PIONEER around IOWA; resolving an intermittent low signal strength problem that was suspected to be EMI related; resolving concerns as to the EME around the RPV while on deck; and making additional measurements as concerns coupling to the Ship's EW systems.

While in the Persian Gulf, the IOWA had become quite convinced of PIONEER's value. Several valuable roles not previously envisioned for PIONEER were found. But there was one problem, the QUICK-GO installed tracking antenna left a significant blind zone forward. Though IOWA was interested, at times, in what was happening where she had been, she was more interested in what was happening where she was going. The present antenna configuration would require her to go where-she was-going backwards in order to utilize PIONEER as a scout! When she returned, she made known that this was simply unacceptable. After a cursory analysis, the decision was made to add a second antenna rather than relocate the present antenna. The first antenna siting was a challenge. The second was more difficult. Ship real-estate is a very valuable commodity. Getting any space is hard, getting a compatible site is often very difficult.

NAVSEA's topside designers and SEMCIP EMC Engineers considered two possible forward facing locations, one at the O10 level and one at the O9 level. Our major concern was about EM coupling to the ship's EW systems. Because of this concern, the O10 location was dropped and NAVSEA agreed with a SEMCIP proposal to make a trial installation for the O9 level position. Temporary scaffolding was erected to make a foundation upon which AAI installed a second antenna assembly. Tests were then accomplished which validated the coupling levels. This testing was completed and then the antenna and scaffolding was removed; all in a week's time. It provided a real, (measured) high confidence data point before the commitment of the funds to make all the drawings for the ship-alt package. The cost is considered to be very small relative to the confidence gained. (This assumes ship time is available at no cost, which is not always the case).

The intermittent low signal strength problem had gotten to the point that it seriously limited the range at which the ship could risk using PIONEER. Several changes were made which finally resolved the problem. Though the problem was found not to be EMI related, SEMCIP made a significant contribution to solving the problem. We were accomplishing MIL-STD-461 type tests on the receiver when the problem occurred. Due to the particular configuration of the system when the problem occurred, we were able to eliminate several potential sources of the problem.

The concern about the EME around the RPV on deck resulted from some signal strength measurements that AAI made. AAI was alarmed by some of the deep nulls they found. We assured them that deep nulls were likely in this circumstance at these frequencies, but that there would still be more than sufficient signal strength for the link with the RPV. AAI asked us to double check with measurements. We did and the values were as we expected.

The final test effort we accomplished involved coupling to other systems. We took some antenna patterns in the near field of the RPV antenna. They showed the predicted 20 to 30 dB dynamic range. This was a disappointment to the AAI engineers who were expecting...
the 50 to 60 dB sidelobes they measured on a range. Then we applied radar absorbing material to the inside of the radome. The area covered was about a fifty degree arc. We were interested to see if, in the cluttered environment of a ship, this application would prove useful. Though one certainly cannot count on spec performance from the RAM, it did reduce coupling by 14 to 20dB in the direction of interest.

360° ANTENNA PATTERN OF AFT ANTENNA

Figure 7

CONCLUSIONS

GENERAL

The below decks CS test environment specified in MIL-STD 461 should be raised from 12.75 volts to about 30 volts (6dB above expected worst cast). Further ship (as well as other platform) testing should be accomplished to determine what source impedance constraints (or power) might be appropriate to accompany this new MIL-STD-461 requirement.

PIONEER

It should be heartening to us and sobering to potential adversaries to see the speed with which we can act to make things happen on ships. PIONEER was installed on IOWA in about a month. Though this haste was probably a contributing factor to the cabling and connector problems, these problems were quickly found and corrected by the well trained SEMCIP/AAI team and hence an acceptable price for the intended goal. This case history confirms that there are certainly likely to be EMI problems when one takes an NDI or off-the shelf system and installs it on a Navy ship. The PIONEER system was not built for a shipboard environment. In fact it was, from an EMI hardening standpoint, a non-MIL-SPEC, commercial system. The good news is that, with a well trained EMI corrective action team working with the systems installation group EMI, problems such as we uncovered can be successfully addressed and need not compromise overall program success.