ORIGINAL ARTICLES

Wavelength Division Multiplexing Over Plastic Optical Fiber Technology (WDM-POF) Onboard Naval Vessel: The Analysis and Component Requirement

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ABSTRACT

This paper discusses the Wavelength Division Multiplexing (WDM) application over the Plastic Optical Fiber (POF) used for data and networks communications of selected equipments onboard a navy ship. Four different wavelengths are used to connect equipments throughout the ship for access by the user, namely; LAN connections, telephone line, CCTV video image and central video/audio entertainments network. Some network topologies possible to be used are explained and improvised mesh topology is studied as possible architecture to be used for this study. The equipments will be able to be controlled and monitored from three different control centers; the Bridge, the Machinery Control Room (MCR) and the Combat Information Centre (CIC) for safety and security connection with redundancy feature, good performance and resilience connectivity. Some parameter such as output power and power losses in the networks were observed. The system promises an enhanced data transfer with the benefits of less overall ship’s weight and therefore will improve the speed and consume less fuel for new and future ship design or ship embarking life extension program.

Key words: POF, WDM, network topology, passive optical component, navy shipboard network.

Introduction

The environment and nature of operations of the current and future naval ships require a compact and complex design of compartments infrastructure and equipments. The combatant ships are designed and built with high-tech equipments to maximize its weapon and sensor power capabilities, high speed acceleration, strike and manoeuvrability for littoral operations with reduced crew requirements and manning. Thus, there is a need for fully automated network-centric ship embedded by redundant systems that is manageable via multi-function operator stations for central and remote controlled and monitored.

Figure 1 shows the example of basic architecture and the control centre of the Ships Combat Management System, Control and Monitoring System and Integrated Communications System. These systems are capable to control and monitor all equipments and systems individually or as an integrated unit. Basic all the equipment and systems may consist of own sensors, controller and transmitters individually, and consequently be interconnected throughout the ship via a backbone or by individual cable in terms of power, control and sensing using numerous amounts of cables. Amazingly, a corvette class ship (97 meters in length) is rigged with more than 80km cables of different types, weighted more than 10 tons (which mostly is high power cables) throughout the ship.

Apparently, reducing a ship’s weight is a primary concern to ship designers, shipbuilders and more importantly to the operator of today. Any weight reduction achieved, either before or after a ship is in service is an immediate benefit to a ship’s operational capability. For example, weight reduction directly affects a ship’s draft and increases the efficiency with which a ship can use its engines (horsepower) for speed and manoeuvrability. Thus, the smaller, lighter and less numbers of cables used onboard will compliment these requirements. Furthermore, ship’s sensors such as surveillance and fire control radar, high power cables and communications antenna emitting excessive amount of electromagnetic interference inside and surrounding the ship.

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Currently, Polymer Optical Fibers (POFs) have proven as an acceptable alternative replacement for the traditional communication means over the use of copper, coaxial cable or even glass fiber for short distance applications. The Fiber-To-The-House (FTTH) technology and automobile industry has propelled the usage POF medium distance and bit rates of 10 gbps. Furthermore, POF is extremely reliable and robust, quick and easy to install, inexpensive, self-powered, provides whole house coverage, work on an unlimited number of outlets, immune to electromagnetic interference (EMI) and super fast data rates of up to one Gigabit per second for Optical Ethernet networks. In compare with glass fiber, POF is more flexible and have larger core diameter and higher numerical aperture, for more of wavelength capacity. These advantages make optical fiber the media of choice for electrically hostile or sensitive environments. All major issues of electromagnetic compatibility (radiated emissions, arcing, static discharge, ground loops, ground offsets, stray currents, etc.) disappear.

**Fig. 1:** Example of architecture for Combat Management System, Control and Monitoring Systems and Integrated Communication and Networks System.

**Fig. 2:** Wavelength Division Multiplex with Optical Multiplexer and De-multiplexer.
The advantages of POF over copper or even glass fiber have encouraged POF to be used widely in various optical networks. The WDM system that allows the transmission of information over more than just a single wavelength (colour) has also increased POF’s bandwidth. In WDM-POF system, many transmitters with different light colours are used to carry individual information. For example, red light of 650nm wavelength is modulated with Ethernet signal while blue, green, and yellow lights carry image information, radio frequency (RF), and television signal, respectively. As shown in Figure 2, WDM-POF system and it functions are represented by the combination of optical signals from multiple different single-wavelength onto a single fiber. Conceptually, the same device can also perform the reverse process with the same WDM techniques, in which the data stream with multiple wavelengths decomposed into multiple single wavelength data streams. The reverse process is called as de-multiplexing.

In this paper, POF will be used as main transmission media for data transfer of LAN networks, CCTV and TV/radio entertainment onboard ship using WDM technology. This approach will be able to replace numerous and complex wiring into much less numbers, highly survival and available to support later extension. The hand made splitter is used and characterized in order to determine the performance of device and the security and accessibility of the network.

Materials and Methods

2. Fiber Optic Onboard Ship:

The utilization of fiber optic as main data communication media onboard ship especially on naval combatant ships is not a new discovery. Equipment such as radars, communications system, combat management system, platform monitoring systems and LAN network have used fiber optic to transfer high rate data within equipment or as main data communication backbone. For instance, the platform monitoring system (PMS) onboard Royal Malaysian Navy (RMN) New Generation Petrol Vessel (NGPV) is using dual redundancy Fiber Data Distribution Integration (FDDI) system to command, control and monitor the platforms onboard the ship. The FDDI architecture onboard NGPV is shown in Figure 3. This FDDI architecture topology is glass fiber based that capable to transport high density data over long distance because the backbone is covering a ship of length of 97 meters. A number of commercial ships are also using FDDI topology as it is a proven system available commercially in the market.

![Fig. 3: RMN NGPV Dual Redundant FDDI for Ship Control and Monitoring Architecture.](image-url)
Results and Discussions

3. POF-WDM Network Architecture:

In this study, single line POF is used to carry multiple wavelengths using WDM technology taking the advantage of its cheaper materials and fragility. Four different wavelengths are used to connect LAN connections, telephone line, CCTV video image and central video/audio entertainments network throughout the ship for access by the user. The controller and server for ship LAN and CCTV video image is at Machinery Control Room (MCR) that located at deck 1 aft of the ship. This is also the location of damage control and fire fighting headquarters onboard. The telephone PABX and central video/audio entertainment network controller is at Main Communication Center located at the centre of the ship on deck 1. The systems are also able to be monitored and controlled from the bridge located at 01 deck where the ship is navigated or from the combat Information Centre (CIC) where the ship warfare tactical information and status is collected, displayed, evaluated, disseminated and controlled for decision by the Commanding Officer.

The CCTV will provide surveillance and monitoring from flood, fire or unauthorised entrance of the high value compartments onboard. The LAN will enable ship staff to access all administration and orders, manuals, publications, maintenance requirements and training document from common area and cabins. The central video/audio entertainments network is providing the ships’ crews with central entertainment such as ship’s live radio, movies and news broadcasted throughout the ship. The controller is placed at ship’s main communication centre. The suggested backbone topology throughout the ship is as shown in figure 4.

![Fig. 4: Deck-by-deck dual redundant POF-WDM backbone architecture.](image-url)

Each deck are interconnected to form a Dual Redundant POF-WDM (DRePOF-WDM) backbone arranged as one ring that interconnected to the equipments and end user devices. The backbone is arranged in mesh
topology via an Optical Add Drop Multiplexer (OADM) which acts as optical switches. These switches will be able to be controlled and monitored at MCR, CIC or bridge for redundant connection through the backbone to ensure survivability and interconnectivity of the network. The connection is shown in Figure 5. The devices need for this system is as follows:

- Coupler/splitter.
- Multiplexer/de-multiplexer.
- Optical Add Drop Multiplexer (OADM).
- Switches from POF.

Fig. 5: Connection from DRePOF-WDM backbone to each deck and equipments.

Figure 5 shows overall arrangement of the system from the backbone to the equipments and the end users located on the various decks onboard the ship. On each deck, equipments and users in the rooms or compartments is linked to the DRePOF-WDM backbone topology using WDM sequenced by time division multiplexing TDM via a transceiver. The multiple different signals enter and exit from the devices onto the single wavelength data streams are done by passive devices multiplexer and de-multiplexer. Many transmitters with different lights colour are used to carry single information. For example, red light with 650nm wavelength modulated with LAN signal while blue, green, and yellow lights carry image information, radio frequency (RF), and video signal, respectively. As shown is Figure 5, WDM is the first passive device required in WDM-POF system and it functions to combines optical signals from multiple different single-wavelength end devices onto a single fiber. Conceptually, the same device can also perform the reverse process with the same WDM techniques, in which the data stream with multiple wavelengths decomposed into multiple single wavelength data streams, called de-multiplexing.

Conclusions:

In conclusion, the Wavelength Division Multiplexing application over the Plastic Optical Fiber was used for data and networks communications of selected equipments onboard a navy ship. The network communication is designed using dual redundancy POF-WDM interconnected deck-by-deck using mesh topology, introducing the design philosophy of Dual Redundant POF-WDM (DRePOF-WDM) backbone network. OADM acts as switches is used to make redundancy circuits. Four different wavelengths are used to connect equipments throughout the ship for access by the user, namely; LAN connections, telephone line, CCTV video image and central video/audio entertainments network. The equipments will be able to be controlled and monitored from three different control centers; the Bridge, the Machinery Control Room (MCR) and the Combat Information Centre (CIC) for safety and security connection with redundancy feature, good performance and resilience connectivity. This system is very promising in enhancing data transfer with the
payback of less overall ship’s weight and therefore will improve the speed and less fuel consumptions of the ship for future new build or ship embarking life extension program. Any system or equipment to be fitted onboard can use this existing DRePOF-WDM backbone.

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