Undersea Optical Communication

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Abstract:
Communication is playing a vital role in the life of human beings from the ancient time. The need to communicate creates a lot of advancement in communication system from time to time. Now a days people are connected world-wide through different communication links. The medium of these communication links could be space, air, surface or water. The underwater optical technology is not new, it has evolved over years and is evolving at fast rate because of its advantages over cables. The paper presents an overview of the development of underwater optical communication over time and the reasons of its increasing demand alongwith the challenges.

Keywords:
submarine cables; transatlantic cable; five sheav gear system; EDFA; AT&T; dark cable

1. Introduction

Optical communication, also known as optical telecommunication, is communication at a distance using light to carry information. It can be performed visually or by using electronic devices. An optical communication system uses a transmitter, which encodes a message into an optical signal, a channel, which carries the signal to its destination, and a receiver, which reproduces the message from the received optical signal. When electronic equipment is not employed the 'receiver' is a person visually observing and interpreting a signal, which may be either simple or complex. Underwater communication has a range of applications including remotely operated vehicle (ROV) and autonomous underwater vehicle (AUV) communication and docking in the offshore industry. Current underwater transmission techniques is primarily utilise sound waves for large distance at lower frequencies and the velocity of sound in water is approximately 1500m/s the resultant communications have problems with multi-path propagation and low bandwidth problems. The use of electromagnetic (EM) techniques underwater has largely been overlooked because of the attenuation due to the conductivity of seawater. However, for short range applications, the higher frequencies and much higher velocity can prove advantageous. The potential of the optical fiber transmission to provide high capacity, reduced circuit cost and compatibility with digital networks makes it very attractive for submarine system.Undersea fiber optic cables make the web

worldwide. Modern cable systems installed upto last year are capable of transmitting about 1000 Gbps over each fiber pair. The earth's continents are connected with a web of undersea fiber optic cables that joins the world's population centers. Anyone who surfs the international web or makes international phone calls on other continents uses undersea fiber optic cables.

2. History

The first transatlantic telephone cable to use optical fiber was TAT-8, which went into operation in 1988. A fiber-optic cable comprises multiple pairs of fibers. Each pair has one fiber in each direction. TAT-8 had two operational pairs and one backup pair. TAT-8 was the 8th transatlantic communications cable, initially carrying 40,000 telephone circuits (simultaneous calls) between USA, England and France. It was constructed in 1988 by a consortium of companies led by AT&T Corporation, France Télécom, and British Telecom. It was able to serve the three countries with a single trans-Atlantic crossing with the use of an innovative branching unit located underwater on the continental shelf off the coast of Great Britain. The cable lands in Tuckerton, New Jersey, USA, Widemouth Bay, England, and Penmarch, France.The system was built at a cost of US$335M in 1988 and retired from service in 2002.This was the first transatlantic cable to use optical fibers, a revolution in telecommunications. The system contained two working pairs of optical fibers. (A third was reserved as a spare.) The signal on each optical fiber was modulated at 295.6 Mbit/s (carrying 20 Mbit/s traffic) and fully regenerated in equipment placed in pressure housings separated by about 40 km of cable. There were several problems with the early reliability of this cable during its first 2 years of operation. The cable was buried on the continental shelf on the European and the American side of the ocean. It was snagged and damaged by fish trawling fleets where burial was ineffective. AT&T laid a trial optical cable in the Canary Islands in 1983. This cable did not have an electrical screen and was attacked by sharks. It was never proved whether these attacks was due to the sharks sensing the electrical radiation from the cable or the vibration of the cable moving on the sea floor where it might have been suspended. TAT-8 did have the screen conductor because of the possible effect of the shark attack. Because the cable was the first fiber optic cable and not coaxial cable, the electrical interference shielding for the high voltage supply lines was removed. This removal did not affect the fiber, but it did cause feeding frenzies in sharks that swam nearby. The sharks would then attack the cable until the voltage lines killed them. This caused numerous, prolonged outages. Eventually, a shark shielding was developed for the cable. PTAT-1, the next cable to go in the Atlantic was put in with the shark shielding and it proved much more reliable than TAT-8.

3. Submarine Communication Cables

A submarine communications cable is a cable laid on the sea bed between land-based stations to carry telecommunicationsignals across stretches of ocean. The first submarine communications cables, laid in the 1850s, carried telegraphy traffic. Subsequent generations of cables carried telephone traffic, then data communications traffic. Modern cables use optical fibertechnology to carry digital data, which includes telephone, Internet and private data traffic. Modern cables are typically 69 millimetres (2.7 in) in diameter and weigh around 10 kilograms per metre (7 lb/ft), although thinner and lighter cables are used for deep-water sections.[1] As of 2010, submarine cables link all the world's continents except Antarctica.

3.1 Importance

As of 2006, overseas satellite links accounted for only 1 percent of international traffic, while the remainder was carried by undersea cable. The reliability of submarine cables is high, especially when (as noted above) multiple paths are available in the event of a cable break. Also, the total carrying capacity of submarine cables is in the terabits per second, while satellites typically offer only 1000 megabits per second and display higher latency. However, a typical multi-terabit, transoceanic submarine cable system costs several hundred million dollars to construct. As a result of these cables' cost and usefulness, they are highly valued not only by the corporations building and operating them for profit, but also by national governments. For instance, the Australian government considers its submarine cable systems to be "vital to the national economy". Accordingly, the Australian Communications and Media Authority(ACMA) has created protection zones that restrict activities that could potentially damage cables linking Australia to the rest of the world. The ACMA also regulates all projects to install new submarine cables.

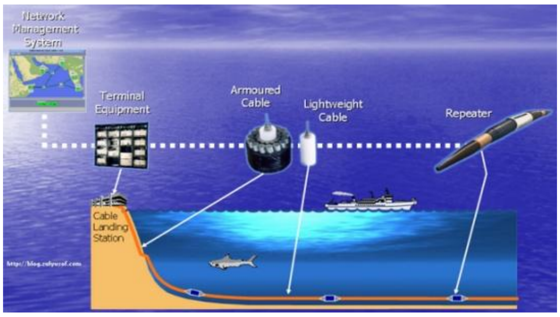

Fig1: Submarine Cable System

3.2 Development

Almost all fiber optic cables from TAT-8 in 1988 until approximately 1997 were constructed by "consortia" of operators. For example, TAT-8 counted 35 participants including most major international carriers at the time such as AT&T Corporation. Two privately financed, non-consortium cables were constructed in the late 1990s, which preceded a massive, speculative rush to construct privately financed cables that peaked in more than $22 billion worth of investment between 1999 and 2001. This was followed by the bankruptcy and reorganization of cable operators such as Global Crossing, 360networks, FLAG, Worldcom, and Asia Global Crossing.There has been an increasing tendency in recent years to expand submarine cable capacity in the Pacific Ocean (the previous bias always having been to lay communications cable across the Atlantic Ocean which separates the United States and Europe). For example, between 1998 and 2003, approximately 70% of undersea fiber-optic cable was laid in the Pacific. This is in part a response to the emerging significance of Asian markets in the global economy. Although much of the investment in submarine cables has been directed toward developed markets such as the transatlantic and transpacific routes, in recent years there has been an increased effort to expand the submarine cable network to serve the developing world. For instance, in July 2009, an underwater fiber optic cable line plugged East Africa into the broader Internet. The company that provided this new cable was SEACOM, which is 75% owned by Africans. The project was delayed by a month due to increased piracyalong the coast. There is only a limited amount of space for cable on land, and this makes the space expensive to rent, and highly competitive. Since 1850 engineers and telecom companies, instead, have been taking advantage of the vast land beneath the oceans to lay cables. The first cables were used to send telegraphy traffic. Since then the cables have been used to send telephone traffic, and most recently data traffic. Many of the modern cables are made of fibre optic, to increase the size and speed at which the information can be sent, and are only 2-inches thick. Trial cables were laid in 1842 in New York harbour and were insulated with tarred hemp and rubber. Nowadays, cables are protected using polyethylene. Traditionally the cables were owned by service providers, yet websites have also started buying submarine cables to control their networks. For example, Google is part of the consortium that manages the Southeast Asia-Japan cable, and Facebook is part of the consortium that manages the Asia Pacific Gateway. Reports in December stated that by owning private networks the companies can stop governments from being able to track what they get up to. As of 2010, submarine cables link all the world's continents except Antarctica. Cables can be broken by fishing trawlers, anchors, earthquakes, turbidity currents, and even shark bites. If cables need to fixed, a repair ship will drop a buoy in the location of the break and a submersible is sent down to repair them.

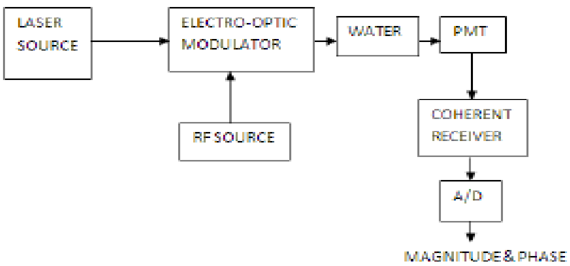

Fig2: Submarine Cable System block diagram

3.3 Underwater cable Network

Buried deep beneath the world's oceans and seas is a network of underwater cables silently connecting even the remotest parts of the world to the web. In fact, almost 95 per cent of the internet we use everyday is carried between countries through these fragile two-inch thick lines - and there is now more than half a million miles of cable underwater. In 2006, submarine cables carried just one per cent of traffic - and increase of 94 per cent in just eight years, according to official figures from the International Cable Protection Committee. Since 2012, the amount of submarine cables has almost doubled from 150 to the current figure of 285. Of this 285, 263 cables are currently in use, while 22 are set to be in use by the end of 2015. When a cable is laid but not in use it is called a 'dark' cable, but once in use it becomes 'lit'.Laying a submarine cable is a remarkably complex, hazardous and expensive business. Routes need to be surveyed, technology developed, the cable needs to be laid without being lost, broken or damaged. The seabed is as hilly, rocky and varied as any terrain on land so undersea cable expeditions have always started with surveys to find relatively flat and unbroken routes. The next problem is keeping the cable safe from accidental damage. The hazards down there include sharks, earthquakes and volcanic activity. Fishermen pose a far worse hazard than fish - deep-sea trawls routinely snag and break cables. These days, new cables tend to be buried using robot submarine ploughs that crawl along the seabed. Specialised cable ships have tanks below deck to store the cables, 'cable engines' that allow the heavy cable to be paid out at a defined rate and sheaves - grooved wheels - to guide it over the bow or stern. Cable ships also have systems that hold the ends of cable lengths together to allow them to be attached ('spliced') to each other. From the 1950s the need to incorporate repeaters (tubular housings containing amplifiers) into telephone cables created a whole new set of handling problems. For repeaters that were too bulky to go through sheaves, The Post Office developed the 'five sheave gear' system that held the ends together under tension with a bypass cable while the repeater was inserted. Later, an even more ingenious Post Office system used rubber tyre wheels to grip the cable - springing apart to allow the repeater to go through.

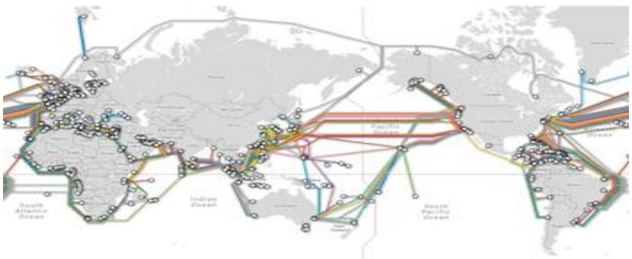

Fig3: Undersea cables around the world

3.4. Advantages of undersea optical communication

The main advantage of underwater optical fiber communication is that the reliability of under cables is high due to extended repeater spacing; especially when multiple paths are available in the event of a cable break. Also, the submarine cables can carry the data in terabits per second capacity, while satellites typically offer only megabits per second and display higher latency.

In submarine cable system, optical fiber is needed which combine low losses with low chromatic dispersion. It has a good mechanical strength for use in demanding environment. Optical underwater communication is an effective alternative to current underwater technology especially in some particular environments such as shallow, coastal and fresh inland water where the use of this approach is useful to overcome all the shortcomings related to the use of acoustic communication and to allow a wide adoption of underwater monitoring systems. In this way, the submarine optical system is found advantageous in several aspects over the other optical systems.

4. Modern Optical Fibre Cables

Modern optical fiber repeaters use a solid-state optical amplifier, usually an Erbium-doped fiber amplifier. Each repeater contains separate equipment for each fiber. These comprise signal reforming, error measurement and controls. A solid-state laser dispatches the signal into the next length of fiber. The solid-state laser excites a short length of doped fiber that itself acts as a laser amplifier. As the light passes through the fiber, it is amplified. This system also permits wavelength-division multiplexing, which dramatically increases the capacity of the fiber. Repeaters are powered by a constant direct current passed down the conductor near the center of the cable, so all repeaters in a cable are in series. Power feed equipment is installed at the terminal stations. Typically both ends share the current generation with one end providing a positive voltage and the other a negative voltage. A virtual earth point exists roughly halfway along the cable under normal operation. The amplifiers or repeaters derive their power from the potential difference across them. The optic fiber used in undersea cables is chosen for its exceptional clarity, permitting runs of more than 100 kilometers between repeaters to minimize the number of amplifiers and the distortion they cause. The rising demand for these fiber-optic cables outpaced the capacity of providers such as AT&T. Having to shift traffic to satellites resulted in poorer quality signals. To address this issue, AT&T had to improve its cable laying abilities. It invested $100 million in producing two specialized fiber-optic cable laying vessels. These included laboratories in the ships for splicing cable and testing its electrical properties. Such field monitoring is important because the glass of fiber-optic cable is less malleable than the copper cable that had been formerly used. The ships are equipped with thrusters that increase manoeuvrability. This capability is important because fiber-optic cable must be laid straight from the stern (another factor copper cable laying ships did not have to contend with). Originally, submarine cables were simple point-to-point connections. With the development of submarine branching units (SBUs), more than one destination could be served by a single cable system. Modern cable systems now usually have their fibers arranged in a self-healing ring to increase their redundancy, with the submarine sections following different paths on the ocean floor. One driver for this development was that the capacity of cable systems had become so large that it was not possible to completely back-up a cable system with satellite capacity, so it became necessary to provide sufficient terrestrial back-up capability. Not all telecommunications organizations wish to take advantage of this capability, so modern cable systems may have dual landing points in some countries (where back-up capability is required) and only single landing points in other countries where back-up capability is either not required, the capacity to the country is small enough to be backed up by other means, or having back-up is regarded as too expensive. A further redundant-path development over and above the self-healing rings approach is the "Mesh Network" whereby fast switching equipment is used to transfer services between network paths with little to no effect on higher-level protocols if a path becomes inoperable. As more paths become available to use between two points, the less likely it is that one or two simultaneous failures will prevent end-to-end service. As of 2012, operators had "successfully demonstrated long-term, error-free transmission at 100 Gbps across Atlantic Ocean" routes of up to 6,000 km (3,700 mi),[21] meaning a typical cable can move tens of terabits per second overseas. Speeds improved rapidly in the last few years, with 40 Gbit/s having been offered on that route only three years earlier in August 2009. Switching and all-by-sea routing commonly increases the distance and thus the round trip latency by more than 50%. For example, the round trip delay (RTD) or latency of the fastest transatlantic connections is under 60 ms, close to the theoretical maximum for an all-sea route. While in theory, a great circle route between London and New York City is only 5,600 km (3,500 mi),this requires several land masses (Ireland, Newfoundland, Prince Edward Island and the isthmus connecting New Brunswick to Nova Scotia) to be traversed, as well as the extremely tidal Bay of Fundy and a land route along Massachusetts' north shore from Gloucester to Boston and through fairly built up areas to Manhattanitself. In theory, using this partly land route could result in round trip times below 40 ms, not counting switching (which is the speed of light minimum). Along routes with less land in the way, speeds can approach speed of light minimums in the long term.

5. Challenges

5.1 Cable Repair: Cables can be broken by fishing trawlers, anchors, earthquakes, turbidity currents, and even shark bites. Based on surveying breaks in the Atlantic Ocean and the Caribbean Sea, it was found that between 1959 and 1996, fewer than 9% were due to natural events. In response to this threat to the communications network, the practice of cable burial has developed. The average incidence of cable faults was 3.7 per 1,000 km (620 mi) per year from 1959 to 1979. That rate was reduced to 0.44 faults per 1000 km per year after 1985, due to widespread burial of cable starting in 1980. Still, cable breaks are by no means a thing of the past, with more than 50 repairs a year in the Atlantic alone, and significant breaks in 2006, 2008, and 2009.

5.2 Third Party Information Extraction

Underwater cables, which cannot be kept under constant surveillance, have tempted intelligence-gathering organizations since the late 19th century. Frequently at the beginning of wars, nations have cut the cables of the other sides to redirect the information flow into cables that were being monitored. The most ambitious efforts occurred in World War I, when British and German forces systematically attempted to destroy the others' worldwide communications systems by cutting their cables with surface ships or submarines.During the Cold War, the United States Navy and National Security Agency (NSA) succeeded in placing wire taps on Soviet underwater communication lines in Operation Ivy Bells.

5.3 Environmental Impact

The main point of interaction of cables with marine life is in the benthic zone of the oceans where the majority of cable lies. Recent studies (in 2003 and 2006) have indicated that cables pose minimal impacts on life in these environments. In sampling sediment cores around cables and in areas removed from cables, there were few statistically significant differences in organism diversity or abundance. The main difference was that the cables provided an attachment point for anemones that typically could not grow in soft sediment areas. Data from 1877 to 1955 showed a total of 16 cable faults caused by the entanglement of various whales. Such deadly entanglements have entirely ceased with improved techniques for placement of modern coaxial and fiber-optic cables which have less tendency to self-coil when lying on the seabed.

6. Conclusion

In context of the undersea telecommunications, it has been reported from the literature that optical fibers have been found of much great importance and advancement in this field. With the experience from previous experiments and new scientific researches we can connect the world in customize manner with ease installation of better reliable and higher bandwidth cables. Optical fibers have been found of much great importance and advancement in this field. Once the cable system was of fixed standard but now they are configurable, expandable, and repairable by demonstrating their feasibility.With better scientific approach the cables are helping us to better understand the oceans and seafloor environmental conditions. It is proposed that the performance of the submarine optical systems can be enhanced with longer distance and more number of channels by employing different transmission systems. Submarine cables also used for otherpurposes then underwater telecommunication such as reservoir monitoring. So with more advance system we can implement the submarine cable for different underwater system.

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