

Undersea Communications Technology

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This introductory paper has two objectives. The first is to offer a high-level overview of AT&T's undersea cable technology, applications, products, and services, including installation and maintenance. This includes a relative historical cost analysis (dollars per Gbits/s per mile), as well as other high-level growth and deployment projections to the year 2000. The second objective is to provide an overview of the articles in this theme issue on undersea communications. Here, the reader will gain an understanding of the topics and their importance to undersea communications, as well as their placement within this issue.

Introduction

This issue of the *AT&T Technical Journal* is devoted to undersea lightwave communications and its technology. Although undersea systems employing lightwave technology are less than 10 years old, this technology has revolutionized global telecommunications in terms of services, capacity, reliability, and quality—compared to prior analog coaxial systems and satellite systems.

Since the deployment of the first deep-water repeatered system between two of the Canary Islands in 1985, undersea lightwave technology has grown to provide wide-band digital connectivity among 60 nations (see Figure 1). This number is expected to grow to 90 nations by the end of 1997.

Currently, third-generation transoceanic lightwave systems are being deployed that operate at 5.0 Gbits/s per fiber pair and use erbium-doped fiber amplifiers (EDFA) in repeaters to boost signals. Similar technology has enabled undersea non-repeatered systems to span distances well beyond 250 kilometers.

The large-scale deployment of undersea lightwave systems has been the direct result of the relationship between economics, service quality, and the ever-growing demand for global communications (see Figure 2). AT&T Submarine Systems, Inc. (AT&T SSI), one of the first AT&T units to be ISO 9001 certified, has installed more than 230,000 kilometers

of undersea telecommunications systems—more than any other company in the world. As the quality of work in this issue indicates, SSI will continue its tradition of technical leadership in supplying and operating quality undersea telecommunications systems.

An Overview of Undersea Systems

Undersea lightwave communications and its technologies have made tremendous progress since the initial deployment in 1985 of the first-generation system operating at 280 Mbits/s per fiber pair. Encouraged by the results of that system, which was deployed over a short distance between two of the Canary Islands, development efforts have produced products that can reliably span oceans with a beam of light that is guided by a hair-thin glass fiber, thus enabling the high-speed digital transmission of voice, data, and video communications.

In 1988, the first transoceanic lightwave system (TAT-8) was installed under the Atlantic to connect France, the United Kingdom, and the United States. This was followed a few months later by a Pacific system connecting Japan and the United States. These first-generation systems are regenerative and operate at 1.3 microns, the so-called second lightwave transmission window. (The other windows of maximum efficiency are 0.83 and 1.5 microns.) At each repeater,

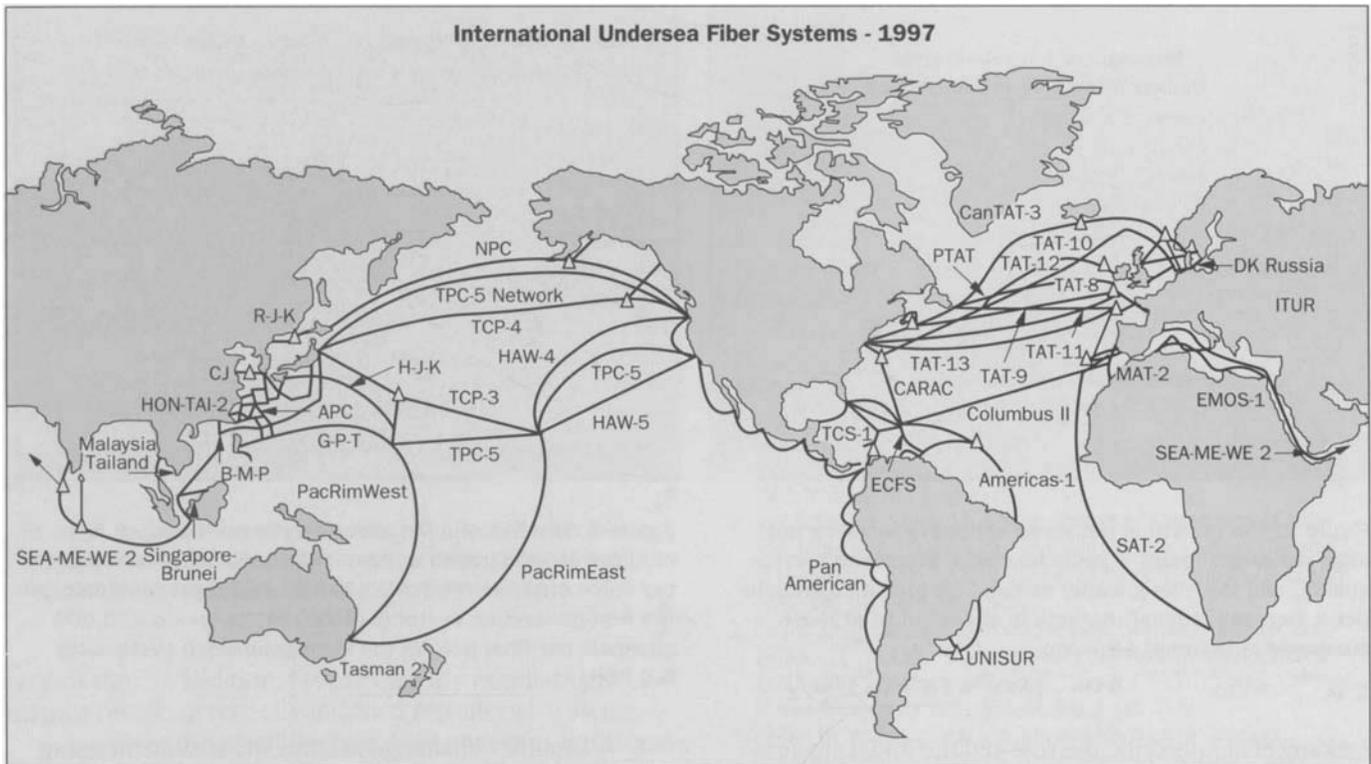


Figure 1. Since the deployment of the first deep-water repeatered system in 1985, undersea lightwave technology has provided wideband digital connectivity among 60 nations, and will connect 90 nations by the end of 1997.

spaced approximately 70 kilometers apart, the incoming optical signal is converted to an electrical signal, regenerated by high-speed integrated circuits, and then retransmitted optically by a local 1.3-micron semiconductor laser.

By 1991, second-generation transoceanic systems operating at 1.5 microns and 560 Mbits/s were being deployed with repeaters nearly twice as far apart as those of the initial systems. This achievement was the result of:

- The development of 1.5-micron single-frequency semiconductor laser technology,
- Greatly improved receiver sensitivity, and
- Lower fiber attenuation at 1.5 microns.

The current, third-generation of undersea lightwave systems use erbium-doped fiber amplifiers to periodically boost the optical signals—without the optical-to-electrical conversions of previous regenerative systems. Third-generation systems operating at 2.5 Gbits/s were deployed in 1994, and systems that operate at 5.0 Gbits/s will be installed this year. The technology used in these systems also enables non-repeatered systems spanning hundreds of kilometers to operate at comparable transmission rates.

This evolution in undersea communications has resulted in an increase in the number of equivalent transmitted voice channels—from 20,000 channels per fiber

Panel 1. Acronyms Used in This Paper

- EDFA — Erbium-doped fiber amplifiers
- ISO — International Organization for Standardization
- SSI — Submarine Systems, Inc.
- TAT — Trans-Atlantic Telecommunications
- TPC — Trans-Pacific Cable

pair in the first-generation systems of 280 Mbits/s, to 320,000 channels per fiber pair in the third-generation systems of 5.0 Gbits/s (see Figure 3). This improvement is even more dramatic when compared to the first analog trans-Atlantic telecommunications cable (TAT-1), which AT&T installed in 1956 with a capacity of only 48 voice-communication channels.

In less than 40 years since the installation of TAT-1, the cost per equivalent voice channel has been reduced by a factor of 1,000 in current-year dollars (see Figure 4). AT&T SSI has helped the telecommunications industry achieve this cost reduction by developing and manufacturing leading-edge technology, developing the most effective and efficient deployment systems, and providing the highest quality construction, maintenance, and operations services.

In This Issue

The papers in this theme issue illustrate the current capabilities of AT&T's undersea lightwave systems and services, as well as some of their future directions.

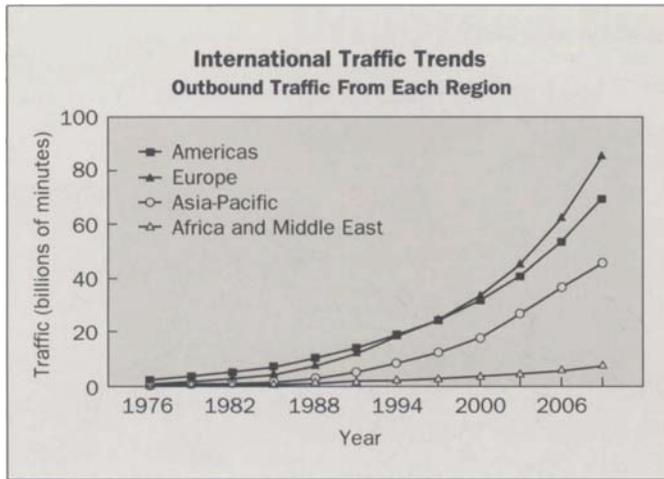


Figure 2. The growth of undersea lightwave systems has been the direct result of reduced costs, increased service quality, and the ever-growing demand for global communications. Demand in most markets is expected to at least quadruple in the next 15 years.

$$10^9 / 5 \times 10^5 = 4 \times 10^4 \quad 4 \times 10^4 \times 6.4 \times 10^4 = 2.5 \times 10^9 \text{ bits/s}$$

Zsakany et al.¹ describe the role and the initial applications of systems in the global network, and review the technology, applications, and architectures. They also discuss the emerging integrated, composite global communications network.

Undersea lightwave systems require special design considerations compared to terrestrial systems. The article by Schesser et al.² describes design requirements for repeatered and non-repeatered systems, and the technology platforms employed to create these systems. They also review system performance parameters that affect the selection of equipment and components.

For transoceanic and many regional applications of undersea lightwave systems, repeaters are required to span long distances. One such example is the trans-Pacific cable system TPC5, in which two systems will be installed, starting in 1995, to form a ring network. Mortenson et al.³ discuss the technology used in such undersea systems for repeatered applications at transmission rates up to 5 Gbits/s per fiber pair. In addition, they describe the various subsystems that are used and the major considerations that must be taken into account to ensure the high performance and reliability required of them.

In many regional and domestic applications, non-repeatered undersea systems are being deployed in lieu of traditional terrestrial-based transmission systems. The article by Stafford et al.⁴ reviews the technological challenges of designing such non-repeatered systems to meet high performance and reliability requirements, yet keep the costs low. They also describe the various subsystems that are used, and report on the results of performance tests of non-repeatered systems.

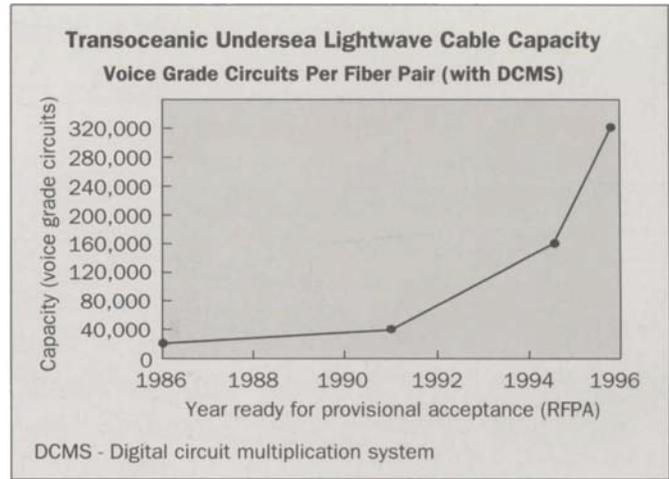


Figure 3. The evolution in undersea communications has resulted in an increase in the number of equivalent transmitted voice channels—from 20,000 channels per fiber pair, in the first-generation systems of 280 Mbits/s—to 320,000 channels per fiber pair, in the third-generation systems of 5.0 Gbits/s.

Another challenge is installing and maintaining undersea lightwave systems. These systems require highly specialized technologies to endure the rigors of the marine environment. The fiber optic cable rests on the ocean floor, which can be as deep as 9,000 meters. The cable also can be subject to mud slides, strong currents, and other marine stresses. The continental shelf is often the location of major hazards, such as channel dredging, fishing nets dragged by trawlers, boat anchors, and even creatures that tend to gnaw on the cable. When damages occur, there must be ways to retrieve and repair the cable. Kordahi et al.⁵ review such topics as route selection, marine tools, automated cable laying, jointing technologies, system test and fault location, and repair techniques.

Supplying third-generation undersea lightwave systems involves more than development, manufacture, and deployment activities. Customers now require undersea lightwave systems to be seamlessly integrated into their total network, including terrestrial facilities. Customers expect network and system planning, as well as operations, administration, and maintenance practices, that are compatible with their current network. Liss and Kurek⁶ describe the coordinated network planning, system planning, and operations, administration, and maintenance activities associated with AT&T SSI's "total solution" to these requirements.

Lynch et al.⁷ report on laboratory "test bed" measurements, in which thousands of kilometers of fiber were coupled with hundreds of optically amplified repeaters. The authors explain how the results of these tests contributed to improvements in system architecture

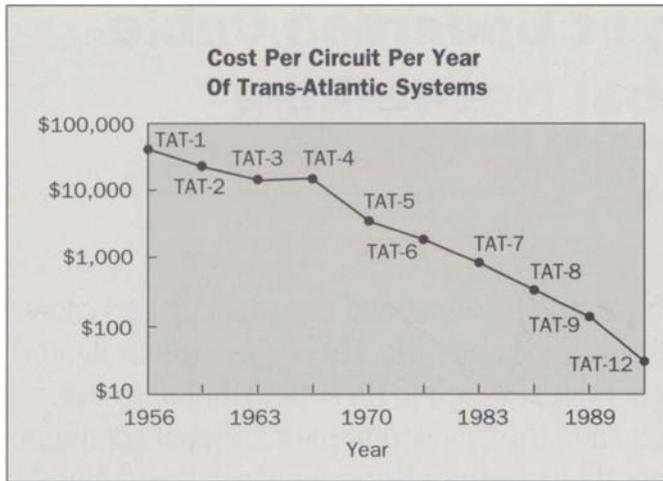


Figure 4. In less than 40 years since the installation of TAT-1, the annual cost per equivalent voice channel has been reduced by a factor of 1,000 in current-year dollars.

and design. In addition, they review the excellent performance results of recently installed repeatered systems.

Over the past 10 years, new undersea lightwave systems have been introduced that significantly outperformed their predecessors. There is every reason to expect this trend to continue. Kerfoot and Runge⁸ explore future technical directions, including employing new transmission formats, such as soliton and multiple wavelengths, for both 10 and 40 Gbits/s optically amplified systems and non-repeatered systems—with spans of well over 500 kilometers.

In Summary

This theme issue provides an overview of both the technologies and applications of state-of-the-art undersea lightwave communications. Deployment of 9,000-kilometer systems capable of transmitting over one million simultaneous conversations soon will seem almost routine, as will the deployment of 500-kilometer systems without repeaters.

We do not know exactly what the future holds. We can predict, however, that the next theme issue of the *Technical Journal* on undersea communications probably will be focused on technological challenges and accomplishments very different from those covered in this issue, as lightwave undersea systems become the backbone of worldwide communications in the 21st century.

While this theme issue contains articles from a few selected authors, this undersea telecommunications revolution could not have been made possible without the contributions of the entire AT&T SSI team, as well as many other individuals and organizations within AT&T. They all are to be congratulated.

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References

1. John C. Zsakany, Nelson W. Marshall, Janet M. Roberts, and David G. Ross, "The Application of Undersea Cable Systems in Global Networking," *AT&T Technical Journal*, January/February 1995, Vol. 74, No. 1, pp. 8-15.
2. Joel Schesser, Stuart M. Abbott, Robert L. Easton, and Marsha Spaulding Stix, "Design Requirements for the Current Generation of Undersea Cable," *AT&T Technical Journal*, January/February 1995, Vol. 74, No. 1, pp. 16-32.
3. Robert L. Mortenson, B. Scott Jackson, Seymour Shapiro, and William F. Sirocky, "Undersea Optically Amplified Repeatered Technology, Products and Challenges," *AT&T Technical Journal*, January/February 1995, Vol. 74, No. 1, pp. 33-46.
4. Elaine K. Stafford, John Marino, and Michael M. Sanders, "Undersea Non-Repeatered Technologies, Challenges, and Products," *AT&T Technical Journal*, January/February 1995, Vol. 74, No. 1, pp. 47-59.
5. Maurice E. Kordahi, Robert F. Gleason, and Ta-Mu Chien, "Installation and Maintenance Technology for Undersea Cable Systems," *AT&T Technical Journal*, January/February 1995, Vol. 74, No. 1, pp. 60-74.
6. Jonathan M. Liss and Kathleen A. Kurek, "Network Planning, Operation, and Maintenance Practices for Undersea Communication Systems," *AT&T Technical Journal*, January/February 1995, Vol. 74, No. 1, pp. 75-82.
7. Robert L. Lynch, Richard L. Maybach, and Philp F. Walch, "Design and Deployment of Optically Amplified Undersea Systems," *AT&T Technical Journal*, January/February 1995, Vol. 74, No. 1, pp. 83-92.
8. Franklin W. Kerfoot and Peter K. Runge, "Future Directions for Undersea Communications," *AT&T Technical Journal*, January/February 1995, Vol. 74, No. 1, pp. 93-102.

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