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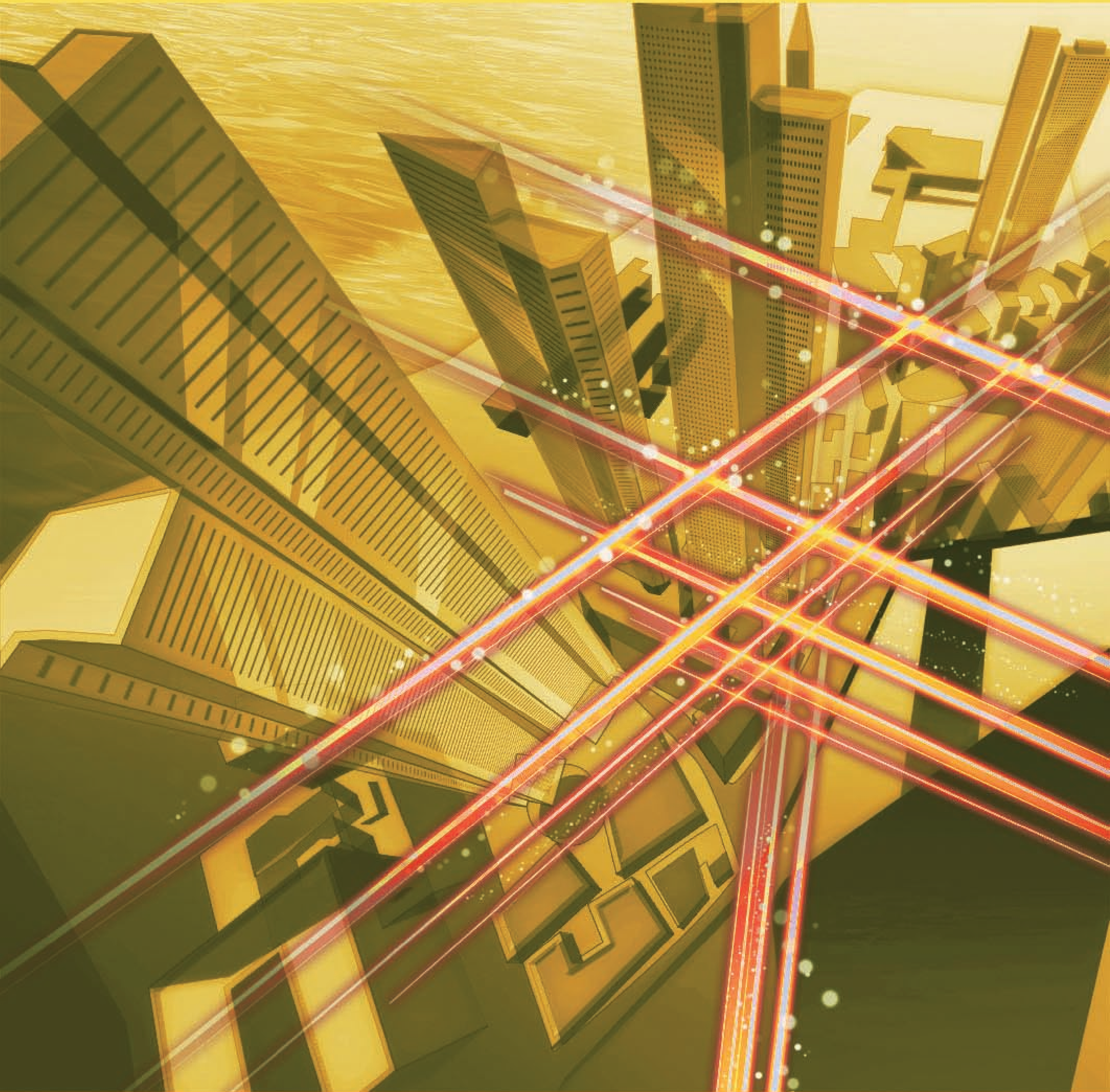

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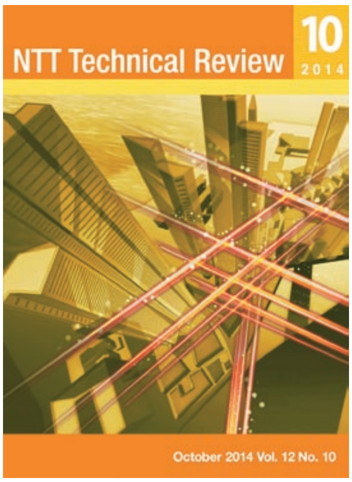

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Taking on the Market with Vision—Using Brand Power to Pioneer Novel Services

Toshihiko Kumamoto, Senior Executive Vice President, NTT WEST

Overview

NTT WEST is executing a variety of measures to survive and thrive in many highly competitive areas. It is involved in a series of new projects such as Smart Hikari Town in various regions in Japan having diverse cultural and social needs. We asked Senior Executive Vice President Toshihiko Kumamoto about the frame of mind that NTT WEST must adopt to ensure growth going forward.

Keywords: management policy, smart city, ICT

Smart Hikari Town project got off to a good start

—Mr. Kumamoto, please tell us about the company's current endeavors in western Japan.

At present, there are more than 8 million subscribers to the FLET'S HIKARI optical broadband service at NTT WEST. We have set a target of 9 million subscribers, and to this end, we are engaged in providing a variety of price plans and a diverse lineup of services. In addition, I feel that we, as a company, have great potential—there are still many things that we can accomplish.

Our work from here on will not simply be the deployment of more optical fiber networks. Rather, it will be to help solve all sorts of problems and issues within the home and the company by making full use of our technologies. In short, we want to make our technologies useful in diverse scenarios of everyday life including education and shopping, emergency/disaster response, and implementation of energy-saving methods.

—Smart Hikari Town seems to be an example of using those technologies in a comprehensive manner.

That's right. Let me tell you about Smart Hikari Town Kumamoto as a showcase example of that.

In 2012, NTT WEST entered into a "comprehensive cooperation agreement for regional revitalization through ICT (information and communication technology) utilization" with Kumamoto Prefecture and Kumamoto City as part of a plan to stimulate regional communities and improve community services. Through this project, we aim to collaborate with local residents on improving community services and achieving a new style of information distribution using ICT. We will explore ideas such as the use of television (TV) technology to monitor elderly people or children who need constant nursing care, and the visualization of current service conditions in municipal bus and railway systems.

In this project, information belonging to the local government and data submitted by residents such as posts in social networking services and word-of-mouth information will be collected and stored on the cloud based on a geographic information system. This huge volume of data in different formats that we call "big data" will be combined and visualized in a form useful for city management. Our target is urban development based on efficient and effective town-type clouds.

This project has gotten off to a smooth start for two main reasons. First, Kumamoto City, among many local governments, is a prefectural capital that has an appropriate scale in terms of population and area. Second, the governments of Kumamoto Prefecture and Kumamoto City have been extremely cooperative in this pioneering endeavor. In this experiment, it will be necessary to test the usability and other aspects of this smart city from diverse viewpoints. These will include our viewpoint as preparers of this environment and the viewpoints of users such as managers of retail stores and their customers.

Actually, we have already collected opinions of people living in the smart city and those of people visiting as tourists and have received comments in line with our expectations as well as comments that we did not expect at all. Some people commented on how they enjoyed the town guidance provided by the region's character mascot named "Kumamon," but others voiced concerns about convenience.

Importance of generating interest in NTT WEST technologies

I believe it is important that we get our customers interested in the services and technologies of NTT WEST, and hearing comments such as "It's interesting!" and "It's fun!" is a good place to start. From the viewpoint of users, it should be easier to become familiar with services and technologies that are interesting and fun to use.

In this regard, NTT Solmare, a subsidiary of NTT WEST, is in the business of delivering content such as e-books (electronic books) and dating games oriented to smartphones, personal computers, and tablets. This year marks the tenth anniversary of its "comic CmoA" e-comic delivery service that has become one of Japan's long-standing top-level sites. It has grown into a hugely popular site focused on worldwide delivery of e-comics. NTT may have an image of being serious and rigid, but our young employees had lots of fun working out ways of displaying cartoon balloons on the screen of a smartphone.

—*Where did this unique approach of NTT WEST originate?*

Each of the 30 prefectures in which NTT WEST provides services includes competing operators. We therefore find ourselves in severe competition with other companies in the Internet communications business, so we regularly have to start various new endeavors in order to maintain a competitive edge. To effectively cover a wide area with many cultural and lifestyle differences, we must first of all provide a high-quality network and other telecommunication infrastructure facilities on a uniform basis. Then, in terms of services, we must make sure that the sales department obtains a firm understanding of the features and needs of each individual area.

We are fortunate to have high brand power in the name NTT WEST that has been nourished since the days of Nippon Telegraph and Telephone Public Corporation. This brand is associated with a "sense of security," that is, an awareness of NTT WEST as a company that will never disappoint its customers when it comes to technology and services. It's true that customers sometimes make comments to the effect that "fees are too high," but this can also be taken to mean that they are using NTT WEST services with confidence and expecting us to work harder to reduce costs.

When sales personnel visit a potential customer for the first time, the familiarity of the NTT WEST brand means that we are almost never turned away at the door and enables us to at least present our proposal to a receptive audience. This is testimony to the trust that customers place in NTT WEST compared with other operators. In addition, we have inherited NTT's long-time reputation of providing "bridges." We have a strong sense of mission to restore telecommunication facilities as quickly as possible when a natural disaster or other mishap occurs so that customers can continue to enjoy services.

With this brand power and worthy mission in hand, we venture forth into the market, but to survive the severe competition that I mentioned, we must create new value such as smart cities and e-comics.

We still have great potential as a company—taking on the market with vision

—In the end, the foundation to such novel services is technological expertise. What message would you have for NTT researchers?

I believe that we have great latent abilities including untapped strategies. As for issues that we need to address, price will always be a matter of concern, but it's technology that supports services and product quality. Technology is continuously evolving, and we must make sure to introduce it in a timely manner to respond effectively to customer needs. It is you, our researchers, who support this technology. I would ask you to keep your eye on the market at all times and to take up the challenge of developing innovative technologies with a sense of vision.

Of course, we at NTT WEST must also face the market with vision and discern customer needs. Going forward, I would like all of us to work together to create convenient, low-cost, and high-quality products. For example, while Japan has achieved a globally high penetration of infrastructure facilities for optical fiber networks, we would like to see more research and development (R&D) done to ensure that the repeater span-length in an optical transmission can be even longer, that the circuit can be switched without interrupting services, and that the network configuration can be simplified.

In addition, the growth in the use of optical broadband service for the home is slowing, so we are very interested in R&D that will enable a greater use of bidirectional communication via TV and Internet lines. We are also interested in the delivery of 4K/8K ultra high-definition video. I'm sure all of you remember the impact of converting from analog to digital media a while back, but I would now like you to pour your efforts into R&D of high-presence video that will generate an even greater impact on users. On our side, we will take a proactive approach to using events such as public viewings as opportunities for exposing our customers to your research achievements.

A change of pace is important—taking a break can raise performance!

—What is important to you in your work?

Today, ICT is more than just a communication tool—it has become an essential means of making our everyday life easier and our business activities smoother. For this reason, I'm sure that the importance of ICT and the convenience that it provides will continue to increase in the years to come. On the other hand, ICT has given birth to conditions in which we are always in contact with someone; that is, we are always in an "active" state. They say it is now difficult to make "downtime" for ourselves in which we can relax and catch our breath.

A 24-hour day is provided equally to all. How those 24 hours are utilized depends, of course, on the individual. For me, dividing up that limited amount of time into active and downtime states is very important. The time that we have to concentrate heavily on things is not really as long as we might think. Moreover, keeping our attention on one thing from one angle may cause us to miss other things of importance. I believe that adding some variety in one's life and changing one's viewpoint and mood from time to time will bring unexpected ideas to the surface. If we don't employ some foresight not only on a day-to-day basis but also over several days or even several months, I think it will be difficult to allocate time in a satisfactory manner.

— Mr. Kumamoto, can you leave us with a message for all NTT WEST employees?

Putting the things that you are involved in to good use in society—such as making the technology that you develop into practical products, turning your designs into actual facilities, and getting our customers to actually use the fruits of our efforts—is one of the great blessings of work. At the same time, relationships with colleagues with whom you work can deepen with each passing year, and the number of people that can come to your aid in times of emergencies can increase. For me, this is the joy of living!

I believe that I would not be where I am today if I did not have such bonds with people. Forming long-time associations with people both inside and outside the company and from a variety of backgrounds can support your individual growth. I would like everyone to put the formation of relationships with all kinds of people regardless of their age or position at the top of their agenda.

Interviewee profile

■ Career highlights

Toshihiko Kumamoto entered Nippon Telegraph & Telephone Public Corporation in 1980. After serving as Senior Manager of the Planning Department and Director of Personnel Department No. 2 at NTT WEST and as Manager of the NTT WEST Kumamoto Branch, he became President of NTT West Home Techno Kansai in 2008, NTT WEST Senior Vice President Tokai Regional Headquarters and Manager of the NTT WEST Nagoya Branch in 2010, and NTT WEST Senior Vice President and General Manager of the Network Department, Plant Headquarters in 2012. He assumed his present position in June 2014.

Maintenance and Management Technology for Safe, Secure, and Economical Operation of Telecommunication Infrastructure Facilities

Fumihide Sugino and Hiroshi Masakura

Abstract

The conduits, manholes, tunnels, and other telecommunication infrastructure facilities that support optical access networks are aging rapidly, just as roads, bridges, and other elements of the social infrastructure are. The ability of these facilities to withstand large-scale earthquakes is also a major concern. These Feature Articles describe the latest technical trends in facilities management, inspection and diagnosis, repair and reinforcement, and technology for making facilities resistant to earthquake damage as part of efforts to achieve safe and secure telecommunication infrastructure facilities as well as economical maintenance.

Keywords: telecommunication infrastructure facilities, maintenance and management, age deterioration

1. Introduction

The aging of roads, bridges, tunnels, and other elements of the social infrastructure is becoming a severe social problem. Dealing with this problem is an urgent matter for governments at the national and local levels and the enterprises that manage infrastructure facilities. However, the huge cost and insufficient number of technicians are hindering an early solution. Furthermore, there is no systematic knowledge or standard technology for dealing with aging infrastructure facilities, so managers of the facilities are left to devise measures individually. Accordingly, there is a growing expectation by governments and society as a whole for the development of technology to address the problem. Another equally important problem is the need to strengthen facilities against major earthquakes. The probability of a Nankai Trough earthquake or an earthquake directly beneath the Tokyo area is high, and the resulting damage to infrastructure facilities, especially facilities deteriorated by age, would be immeasurable.

NTT telecommunication infrastructure facilities, including conduits, manholes, and tunnels, would not escape that damage. For example, about 80% of the manholes will be over 50 years old (the service life for such facilities) by 2030 (**Fig. 1**). Currently, 80% of the existing conduit is not equipped with earthquake resistance measures, and the problems that require solutions are mounting. In developing new business on the B2B2C (Business-to-Business-to-Consumer) model, NTT is pressing forward with the expansion of optical access systems, and having safe and secure telecommunication infrastructure facilities is important in order to provide stable support of such NTT services.

Research on telecommunication infrastructure facilities at the NTT Access Network Service Systems Laboratories has spanned many years, and we are applying the technology and research expertise

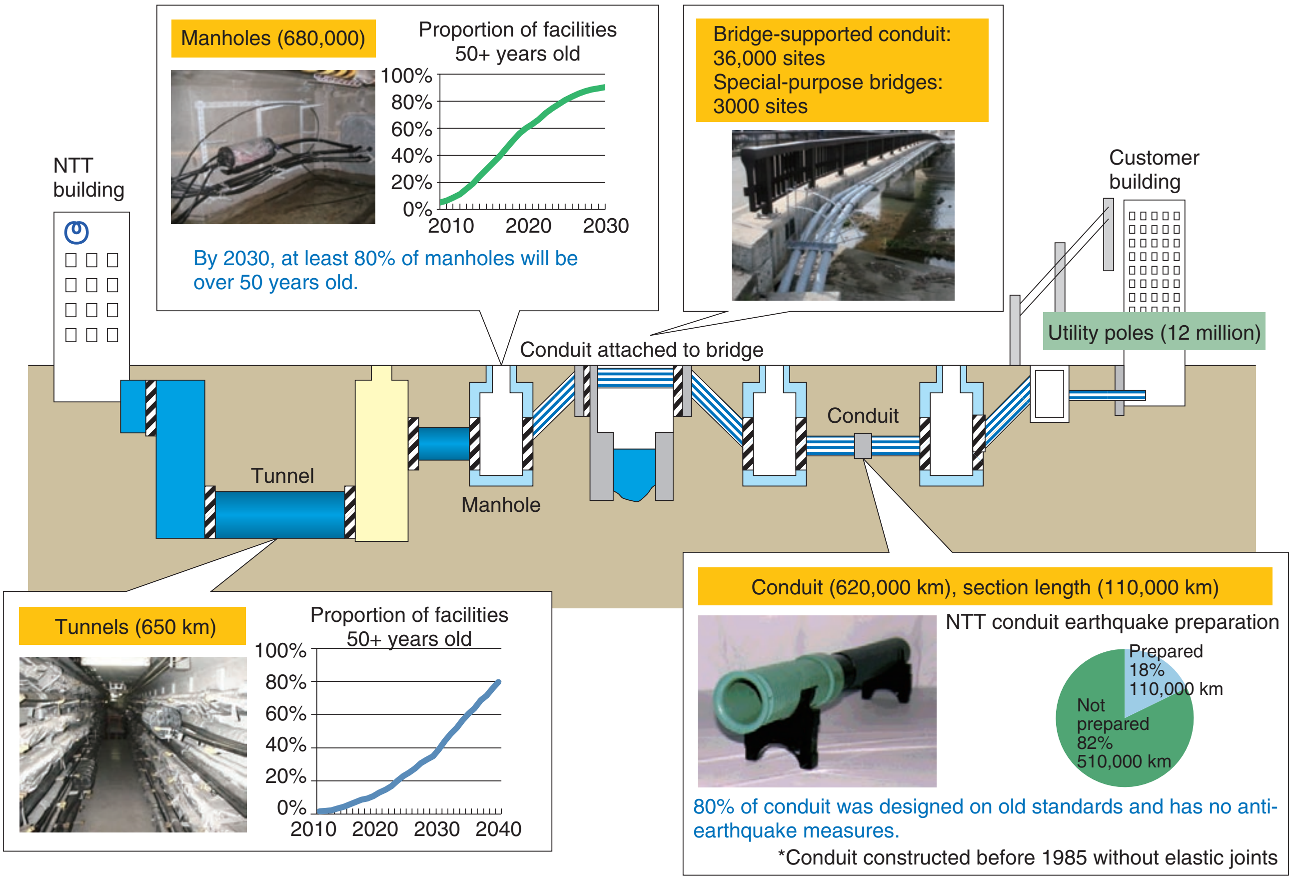

Fig. 1. Telecommunication infrastructure facilities.

we have developed while gathering knowledge acquired by other NTT laboratories and other companies to solve such problems.

2. Direction of research and development (R&D) related to telecommunication infrastructure facilities

The NTT Access Network Service Systems Laboratories is concentrating on developing maintenance and management technology for safe, secure, and economical maintenance of telecommunication infrastructure facilities. By making the results of that work widely applicable to infrastructure facilities in Japan and other countries, rather than only within NTT, we hope to contribute, if only to a small degree, to solving a problem faced by society in general.

In our R&D on maintenance and management technology, we are going beyond the conventional research topics such as repair procedures and tools for inspection and diagnosis, by taking an overall view of the maintenance and management performed by NTT business companies and working on more innovative management strategies. We cannot keep up with the rapid aging of a huge number of facilities by increasing the efficiency of individual inspection and repair tasks alone. We can see by looking at the maintenance and management cycle (**Fig. 2**) that a radical change is needed. We are focusing on this challenge from the three viewpoints described below.

2.1 Facility-specific management techniques based on prediction of degradation and damage

The plan used to manage the entire maintenance and management cycle is based on facility management criteria such as inspection interval, inspection items, confirmation of degradation, and the timing of repair and reinforcement work. However, most of those criteria were set with reference to general structures that existed at the time the telecommunication

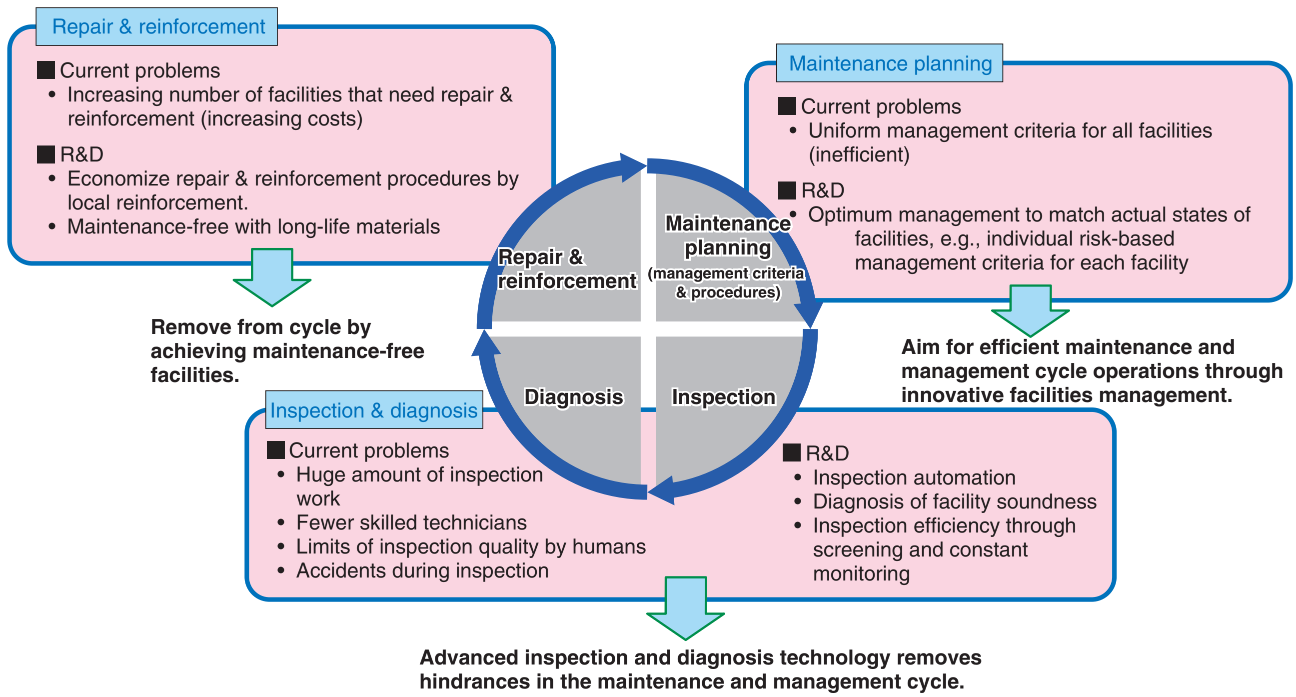

Fig. 2. Maintenance and management cycle and R&D efforts.

infrastructure facilities were constructed, a time when awareness of maintenance and management was relatively low. The criteria are even ambiguous as a basis for engineering. The NTT Access Network Service Systems Laboratories is proceeding with R&D on facilities management technology for revising such management criteria for NTT facilities to match current maintenance needs.

For example, even for facilities that were constructed with specifications that are nationally uniform, the degree of deterioration from aging, the earthquake damage rate, and the impact of facility failure can all vary with the facility environment. Our objective, therefore, is to create a more efficient maintenance and management cycle achieved by using detailed criteria that take the conditions of individual facilities into account instead of using uniform criteria for all facilities.

Achieving that objective requires technology for evaluating the states of individual facilities and for predicting degradation and damage. Such predictions can be made by understanding the mechanism of deterioration with age, identifying points that are weak against earthquake damage, and analyzing the enormous amount of accumulated inspection data. Doing so would make it possible to set priorities and optimize timing for facility inspection, repair, and implementation of earthquake countermeasures. It would also become possible to examine the inspection items and procedures for each facility in more detail.

When all facilities are new, the total repair cost can be effectively held down by considering the life cycle cost and inspecting all of the facilities uniformly, and by repairing facilities whenever slight degradation was found. However, under conditions where all facilities are aging, such as the conditions that exist now, facilities management must consider the risk of facility failure as well as the total repair cost. The objective of the NTT Access Network Service Systems Laboratories is to establish a management method that takes the probability of facility failure and the effects of a failure into consideration [1] [2].

2.2 Inspection and diagnosis automation with images and sensors

The aspect of maintenance and management that most requires skilled technicians is facility inspection. Inspection is difficult because the number of facilities is immense, facilities are spread widely across the country, and they are installed under roads and on bridges. With the declining number of skilled technicians, inspection has become the primary cause of delays in the maintenance and management cycle. Also, the ceiling collapse in the Sasago Tunnel spurred a move toward stricter inspection of the nation's facilities. As a result, NTT business companies now regard improvement of inspection efficiency and quality as the most important problem in terms of maintenance and management.

We are working on ways to solve that problem by developing technology for automating the inspection work that is now performed using human vision and touch. This technology includes the use of image processing, sensors, and robots. In addition to the obvious objective of higher efficiency, we are also targeting inspection results that are more accurate without depending on the skill of the technician, inspection of parts that cannot be seen by human inspectors, and diagnosis of facility soundness using ways that cannot be done by human inspectors. Inspection automation can also effectively increase worker safety by reducing the work done by humans at dangerous sites such as on roadways or in high places.

On the other hand, however, simply automating the work will not lead to a radical solution from the viewpoint of efficiency. Achieving efficiency of maintenance and management cycles more quickly requires inspection by using facility screening as well as inspection technology that is suited to screening. Rather than carrying out detailed inspections of the huge number of facilities one by one, we can analyze data collected from sensors installed in facilities and image data from vehicle-mounted cameras in order to identify facilities that should be thoroughly inspected. Doing so can avoid risk and greatly reduce the number of inspections that take place. While moving forward with this R&D, we are also looking towards the future challenge of realizing technology for 'unconscious inspection' by continuous monitoring, in which the facilities themselves transmit data [3].

2.3 Economical repair and reinforcement technology for extending service life

NTT's basic stance is to extend the service life of aged telecommunication infrastructure facilities without having to renovate them. To more economically perform the increasing amount of repair and reinforcement work, and to extend the service life of facilities, we are moving forward with R&D on technology that takes the special features of NTT facilities into consideration. Examples include technology for repairing conduit with telecommunication cable in place and without interrupting service, and methods for accurately determining age deterioration, weak points susceptible to earthquake damage, and the residual strength of each facility part by part so that repairs can be completed with the minimum necessary local reinforcement. Another objective is to ultimately break free from the maintenance and management cycle itself by taking measures to control degradation when repair and reinforcement work is done and achieve maintenance-free facilities that have a perpetual service life.

Although there is currently very little construction of new conduit and manholes, it is assumed that the relocation work will increase when age-deteriorated roads and bridges attached to NTT conduit and manholes are repaired or renovated. To reduce the cost of any new construction that is required, we are also investigating facilities for which there is no concern for age deterioration and which require no inspection, and simple, economical facilities that are limited to optical cables, with a view to the future all-optical network [4] [5].

3. Future development

Telecommunication infrastructure facility construction technology has developed around what is known as civil engineering technology. However, the maintenance and management technology described in this article essentially requires certain application technologies from other fields as well as combined use of various technologies. Those fields include materials technology, device technology, image processing technology, and wireless and other telecommunication technology, as shown in **Fig. 3**. In that respect, a major strength of the NTT laboratories is the advanced research in diverse fields centered around telecommunications technology. The NTT Access Network Service Systems Laboratories is proceeding with R&D in cooperation with the NTT Energy and Environment Systems Laboratories, NTT Device Technology Laboratories, and NTT Media Intelligence Laboratories. We will aim for innovative technology by further strengthening and expanding this cooperation between laboratories and applying the strengths of the NTT laboratories in our future work. Beyond NTT R&D, we are also aiming for technology that can be applied to facilities around the world and the development of new services and business opportunities that apply that technology. We will work to achieve those goals by deepening cooperation with universities and other sources of expertise

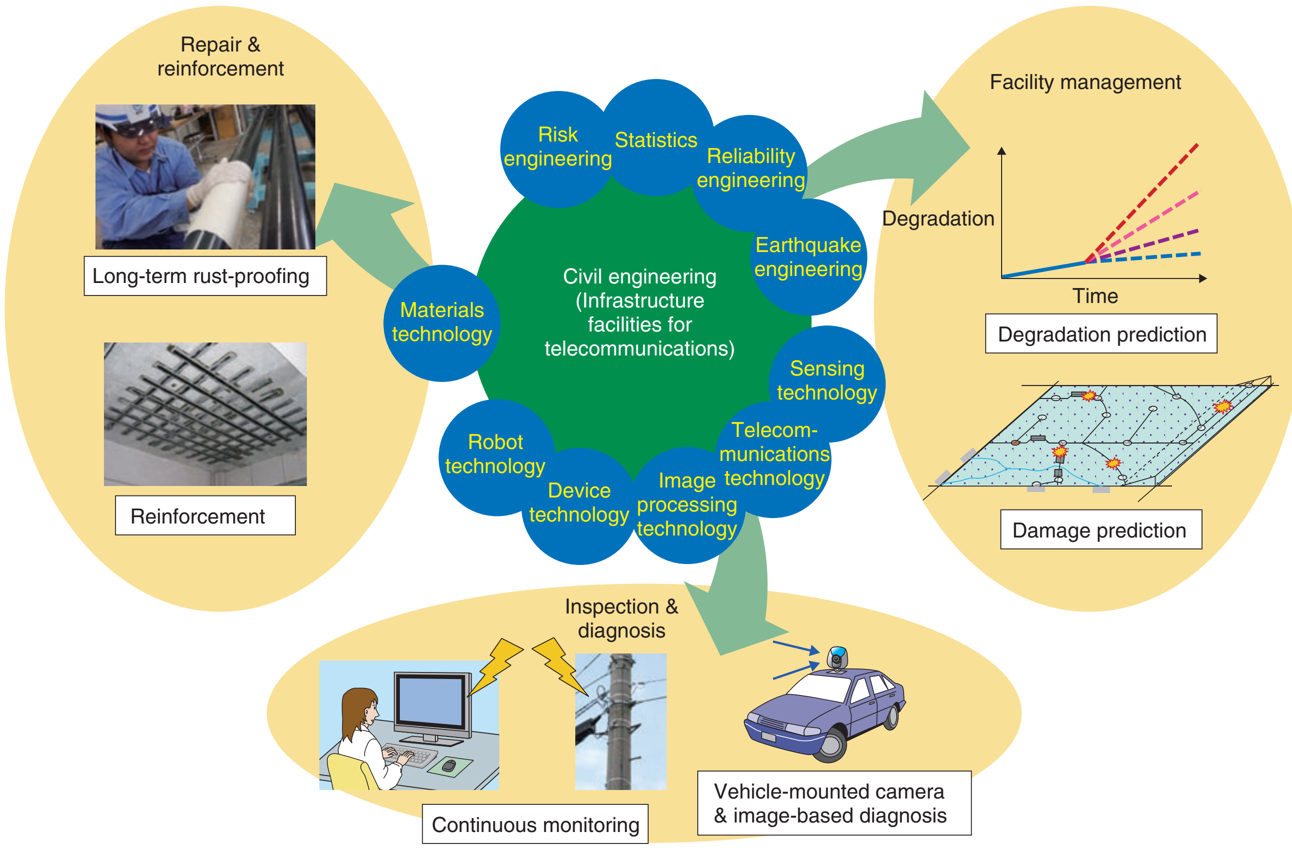

Fig. 3. Maintenance and management technology R&D.

and exchanging ideas with other infrastructure enterprises that face the same problems, while making continued efforts to extend our knowledge of industrial fields other than those related to infrastructure. Currently, aging and the lack of resistance to earthquake damage are important problems for social infrastructure facilities, including NTT facilities. The NTT laboratories will address that problem head-on and continue to conduct R&D that can contribute to society in general as well as meet the expectations of NTT business companies and NTT Group companies.

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He received the B.E. in civil engineering from Hokkaido University in 1987 and joined NTT the same year. He has studied ACEMOLE construction technology, which is a construction method that does not require road excavation. He has also worked at NTT EAST. His main field of work was telecommunication infrastructure such as cable tunnels and underground pipeline systems. He has been in his present position since 2012 and is currently studying NTT infrastructure.

Hiroshi Masakura

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He received the B.E. in civil engineering from Ehime University in 1989. He joined NTT in 1989. He is engaged in R&D of communications-infrastructure facilities. He was previously with NTT Access Network Service Systems Laboratories. He took up his current position in July 2014.

Facilities Management Technology for Optimizing Inspection and Repair Timing

Kazuyoshi Kawabata, Jiro Mori, Yasuhiro Katsuki, and Sho Ashikaga

Abstract

The huge number of telecommunication infrastructure facilities that support information technology services continues to deteriorate from aging, and the number of technicians available to conduct maintenance is decreasing, so maintenance and management methods that are both practical and economical are needed. To meet this need, we are carrying out research and development on facilities management technology for setting inspection and repair criteria according to the state of each facility as determined by degradation prediction. This article describes our work on facilities management technology and our maintenance and management methods for manhole inspection.

Keywords: infrastructure facilities, maintenance and management, degradation prediction

1. Facilities management technology

1.1 Background and problems

Facilities management technology provides maintenance and management criteria and methods for the efficient management of the Plan-Do-Check-Act (PDCA) cycle as a series of maintenance tasks that includes facility inspection, diagnosis, repair and reinforcement, and maintenance planning (**Fig. 1**). The ceiling collapse in the Sasago Tunnel in 2012 heightened concerns about infrastructure safety within Japan, and infrastructure maintenance and management efforts have since increased further in importance. However, various challenges arise in terms of maintenance. The maintenance of telecommunication infrastructure facilities involves three particular problems:

(1) Facilities are aging, and the number of maintenance technicians is decreasing; consequently, the efficiency of maintenance work must be increased in order to cope with these issues.

(2) The current uniform management criteria must be revised, and a management method that can deal with individual cases of degradation that arise according to installation conditions and other factors must be developed.

(3) There is a need for cooperation with the managing authorities of the roads under which facilities are installed and with other companies that install underground infrastructure elements.

We are working on a plan for maintenance and management of telecommunication infrastructure facilities based on preventive maintenance, in which inspections are done and measures are taken before problems occur. To avert the risk of facility failures, preventive maintenance involves uniform, comprehensive, and periodic inspections of all facilities and the implementation of repairs and renovation as needed. However, the cost and labor required simply to inspect the huge number of aging facilities alone is very high. To deal with that problem, we are aiming to optimize the timing of inspections and repairs based on an evaluation of the state of individual facilities and on predictions of their eventual degradation (**Fig. 2**) [1]. That requires technology for understanding the degradation mechanism and for

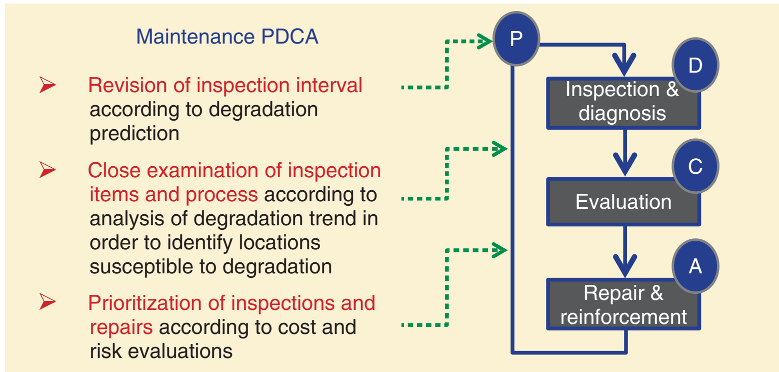

Fig. 1. PDCA cycle of maintenance tasks.

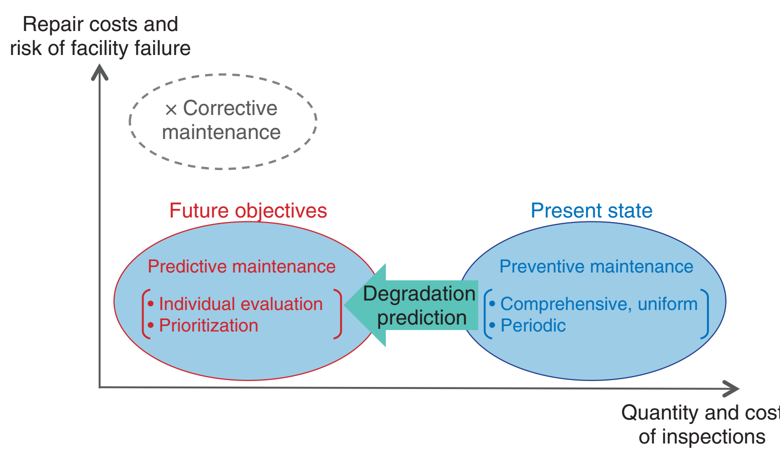

Fig. 2. Target for future maintenance plan.

prediction of degradation, and technology for evaluating degradation and residual strength.

1.2 Features of telecommunication infrastructure facilities

Manholes and tunnels are constructed of steel-reinforced concrete. Past research on the degradation mechanism of concrete structures and research on maintenance and management methods has mainly focused on roads and railway structures, and much knowledge has been obtained. Compared to roads and railway structures, telecommunication infrastructure facilities are small, individual structures that all have roughly the same specifications. Because the facilities are buried underground, the environmental conditions are more limited than those of outdoor structures. Also, the number of facilities is huge. For these reasons, it is important to identify methods that are particularly suited to telecommunication facilities as we review research on road and railway structures.

Manholes are currently the facilities that are most numerous and that require a substantial amount of inspection work. We are working on a maintenance and management method that takes the features of manholes into account.

1.3 Cooperation with other infrastructure enterprises

In addition to referring to past research on roads and railway structures, our research and development (R&D) on maintenance and management methods includes exchanging ideas on inspection work with other infrastructure management authorities and

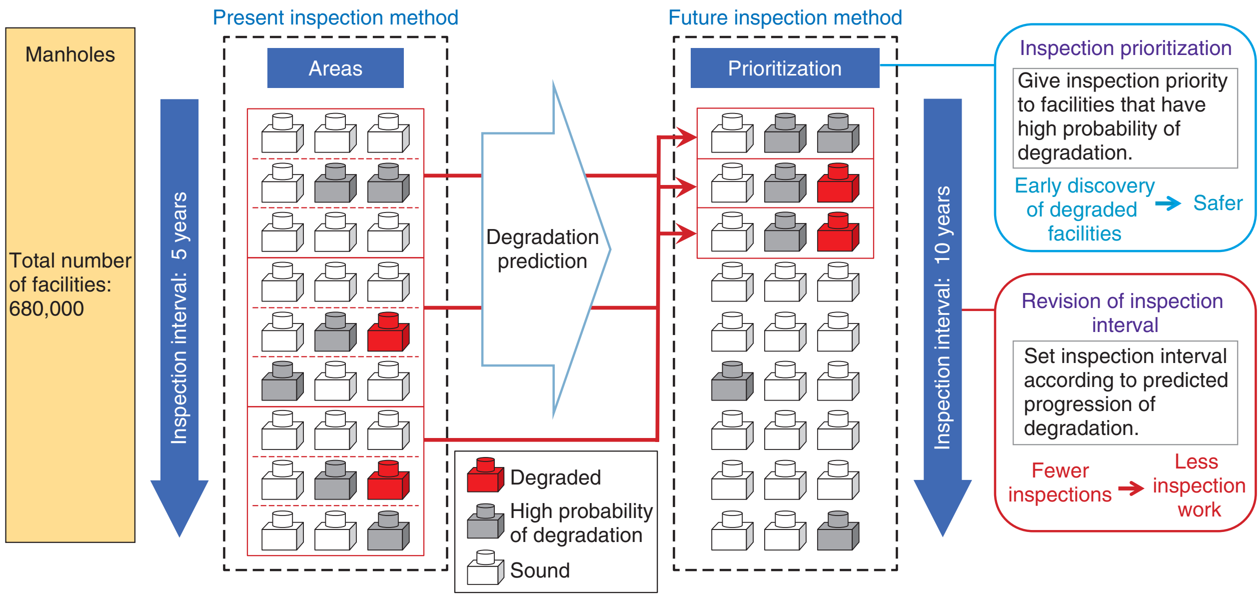

Fig. 3. Manhole maintenance process.

enterprises. As part of that, we are participating in the Research Initiative for Advanced Infrastructure with ICT (information and communication technology) offered by the University of Tokyo Interfaculty Initiative in Information Studies [2]. In addition to conferring with infrastructure enterprises such as the East Japan Railway Company, Tokyo Metro Co., Ltd., and the Metropolitan Expressway Company Limited as well as with university scholars, we are engaging in discussions on the sharing and analysis of problems related to infrastructure management and the proposal of improvement and operation methods. The research initiative involves analyzing some of the inspection data obtained using the manhole inspection prioritization technology. Also, NEXCO East Japan (East Nippon Expressway Company Limited) and the Tokyo Electric Power Company, Incorporated (TEPCO) will join the initiative in 2014. TEPCO also manages manholes and other facilities of the same types managed by NTT, so we expect even more fruitful activities.

2. Manhole maintenance and management methods

NTT has about 680,000 manholes throughout Japan, and about 80% of them are at least 30 years old. Some are beginning to show deterioration from aging, which will continue in the future, so early discovery of degraded facilities and appropriate maintenance are required. Currently, manhole inspection is done area by area at a uniform inspection interval for all facilities. However, manhole degradation does not occur consistently with the age of the facility, but varies with the installation environment and structure. Our objective for the future is to apply practical inspection timing in which the progression of degradation is predicted for each manhole and inspections are performed with priority given to facilities that have a high probability of degradation, while the inspection interval is extended for other facilities (**Fig. 3**).

2.1 Manhole inspection prioritization technology

We used FEM (finite element method) analysis* to clarify the relation between outside forces that act on the facilities and the installation environment, and cracking that occurs inside manholes. We used the results to analyze existing inspection data in order to identify the inspection items and installation conditions on which an inspection judgment of *degraded* is based. The result is that we were able to determine which facilities have a high degradation probability [3].

* FEM analysis: The method of analysis in which a continuum that has infinite degrees of freedom is approximated by using a region that contains some specified finite number of unknown quantities or a finite set of elements to solve an engineering problem.

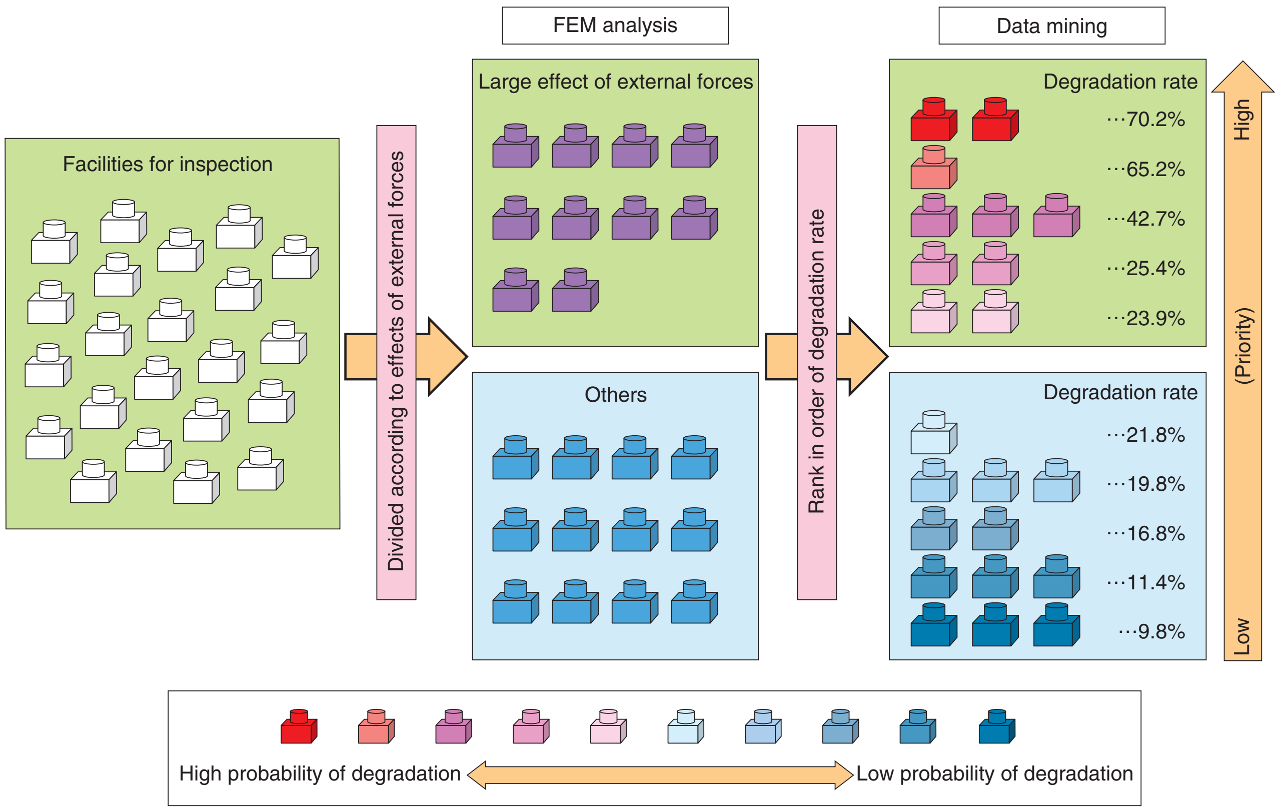

Fig. 4. Assignment of priority.

First, facilities are sorted according to whether or not they are in installation environments where the effect of external forces may cause cracking. The data are then analyzed in order to classify the facilities according to the probability of degradation. Manholes that are subjected to large external forces and have a high probability of degradation can then be given priority in inspection (**Fig. 4**).

We analyzed about 20,000 inspection data values and assigned priorities for the 7600 manholes to be inspected in the future. In 2013, about 2700 inspections were done, largely in order of priority. The degraded facility discovery rates (number degraded/number inspected) were 9.5% for all of the inspection data collected so far, 14.2% for the prioritized facilities, and 13.3% for the actual inspection results. In the actual inspections, too, the discovery rate was higher than previously obtained by a factor of from 1.4 to 1.5, close to what was expected.

The former area-based inspection scheme allowed efficient setting of inspection routes. Inspection sites selected according to priority, however, might be scattered over a wide area, making inspection work inefficient. In practice, however, manholes that have relatively high repair priorities tend to be clustered together, so there was no actual decrease in efficiency due to inspection routing.

The results described above confirm both the practicality of this method for actual inspection work and the effectiveness of early discovery of degraded facilities.

2.2 Revision of manhole inspection interval

Currently, the manhole inspection interval is about five years, but it is desirable to set the interval so that it matches the progression of manhole degradation. We therefore proposed a method of setting the manhole inspection interval based on the level of rebar corrosion risk determined according to an understanding of the manhole degradation process obtained by observing the progression of rebar corrosion within the concrete.

The process of degradation by rebar corrosion in ordinary steel-reinforced concrete structures is illustrated in **Fig. 5**. There are four levels of risk: *latent*, which is prior to the beginning of rebar corrosion;

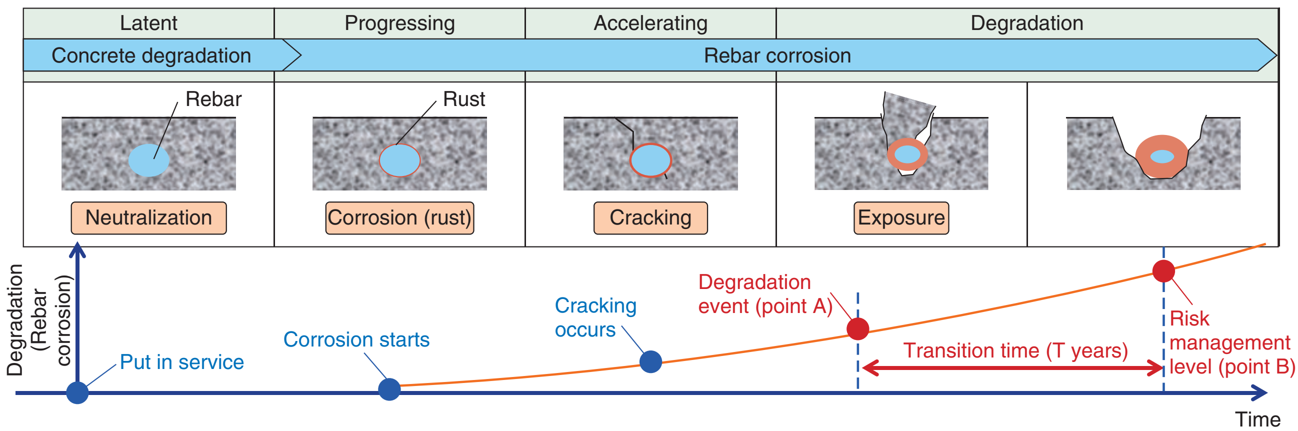

Fig. 5. Process of degradation in reinforced concrete.

progressing, in which rebar corrosion has begun but no degradation is apparent on the surface of the concrete; *accelerating*, after cracking has appeared; and *degradation*, where concrete has actually separated or fallen off, and protection of the rebar is compromised. Point A is where degradation can be confirmed visually, point B is the rebar corrosion state that determines the risk level, and T (years) is the time for the transition of rebar corrosion from point A to point B. To detect point A by inspection before point B is reached, the inspection interval must be set to T years or less. That is to say, if the state at the time of the inspection is before point A, point B will not be reached after T years with no measures taken at the time of the next inspection. If degradation of point A or later is confirmed at the time of the periodic inspection, the arrival at point B at the time of the next inspection T years later can be prevented by undertaking some repairs or other measures.

Data from past studies and the results of further on-site investigations show that if point A is taken as the point of rebar exposure and point B as the criteria for required repair of cut-and-cover tunnels, the transition time from point A to point B (T) with a rebar corrosion rate of 15% is about 10 years. Because 'exposed rebar' is a phenomenon that can be confirmed visually, the inspection can be done without a great change in the conventional inspection work flow. These results suggest that the current inspection interval of five years can be extended in order to increase the economy of inspections. (The results for this finding were obtained in June 2014.)

3. Future development

Our future work on maintenance and management methods for manholes will aim to improve the accuracy of predicting the degradation progression that takes into account the environmental conditions of individual manholes. We also plan to investigate the extension of these methods to tunnels and other facilities. Although the studies of maintenance and management methods have assumed periodic visual inspections as currently done, future R&D on facilities management technology will build on trends in inspection technology in which other techniques are applied.

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Protecting Telecommunication Services from Earthquake Damage

Katsumi Sakaki, Koji Tanaka, Masato Wakatake, and Akira Ito

Abstract

To protect telecommunication network facilities from damage caused by major earthquakes, NTT Access Network Service Systems Laboratories has been continuously conducting research and development on technology to make the telecommunication infrastructure resistant to earthquakes and to improve the accuracy of evaluating earthquake resistance. This article describes our work to improve the technology for evaluating non-standard private bridges that was introduced in 2013 as a measure to improve the earthquake resistance of important facilities. It also describes the technology currently under development for evaluating the earthquake resistance of conduit.

Keywords: earthquake resistance technology, private bridge, damage estimation technology

1. Introduction

The 2011 Great East Japan Earthquake and Tsunami caused enormous damage to the telecommunication infrastructure. The government warns that we will remain susceptible to large-scale damage from earthquakes that originate in the Nankai Trough or directly beneath the Tokyo area well into the future. Therefore, the need to strengthen facilities to make them safer and more resistant to earthquakes is higher than ever.

NTT Access Network Service Systems Laboratories is working to improve the reliability of telecommunication infrastructure facilities based on an analysis of damage to facilities caused by major earthquakes that occurred in the past. In particular, since the Great Hanshin Earthquake in 1995, the earthquake resistance of cable tunnels and standard private bridges, which are important infrastructure facilities, has been evaluated according to new criteria based on the definition of a Level 2 Earthquake by the Japan Society of Civil Engineers. In addition, measures to protect structures in the event of large-scale earthquakes have been applied. This article describes the evaluation technology introduced in 2013 for improving the reliability of earthquake resistance of non-standard private bridges (defined in section 2).

Much importance has been placed on strengthening underground pipeline systems located in areas likely to experience ground liquefaction during earthquakes. Improvements such as making conduit joints flexible have been made, and the effectiveness of these measures was evident after the Great East Japan Earthquake in 2011 and other major earthquakes. However, these earthquake-resistant joints are applicable only for newly constructed facilities; they are not currently used to update conduit that was constructed and installed before the improvements were introduced.

Therefore, technology has been developed for improving the earthquake resistance of old, standard conduit that is already installed without having to excavate it. The result of this development is the pipe insertion type (PIT) new conduit method, which has been confirmed to reduce damage from earthquake motion and ground deformation through the use of a free-standing lining [1].

Currently, technology for evaluating earthquake resistance is being studied in order to effectively apply renovation technology such as the PIT method to the huge quantity of existing standard conduit. We have adopted a macro-evaluation method (**Fig. 1**) to determine the degree of damage and the number of

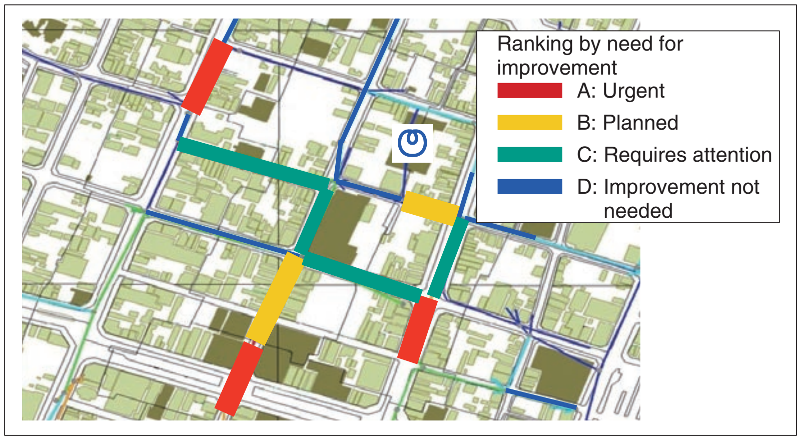


Fig. 1. Current earthquake-resistance evaluation technology.

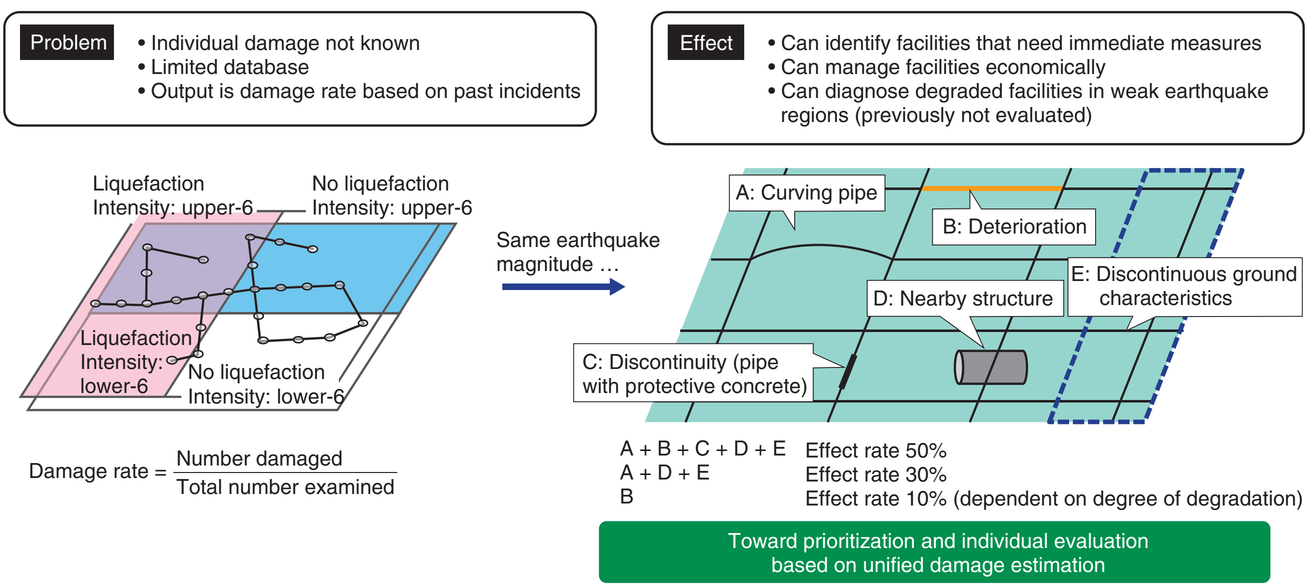
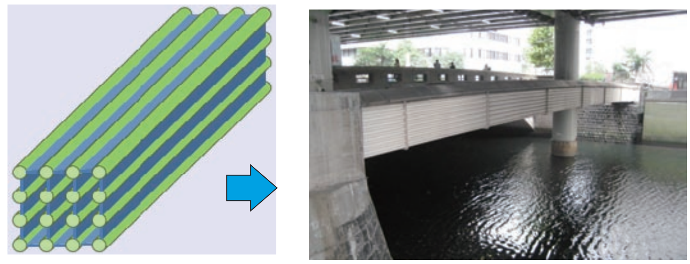


Fig. 2. Highly precise damage estimation technology (concept).

damage incidents that may occur in a wide area in the event of an earthquake. This method uses a statistical analysis of damage from past earthquakes based on the relationship of the earthquake magnitude, whether liquefaction occurred, the type of conduit pipe, and the age of the structure. For example, the damage rate is A% for a steel pipe constructed before 1985 that is exposed to an earthquake measured at upper 6 on the Japan Meteorological Agency seismic intensity scale with liquefaction. That method has been used to predict damage from a major earthquake that is expected to occur in the near future [2].

A problem with this method, however, is the difficulty in evaluating with precision individual sections of conduit in order to decide where to begin implementing measures to strengthen the huge number of old conduit pipes against large-scale earthquakes. Currently, we are aiming at developing technology for identifying the specific weak points of individual pieces of conduit (**Fig. 2**). Our specific objective is to achieve technology that will enable highly accurate damage prediction through quantitative evaluation of

Bridge with jointed steel pipes: Conduit pipes are welded together with steel straps.



Bridge without beams: Conduit pipes are supported by separated girders.

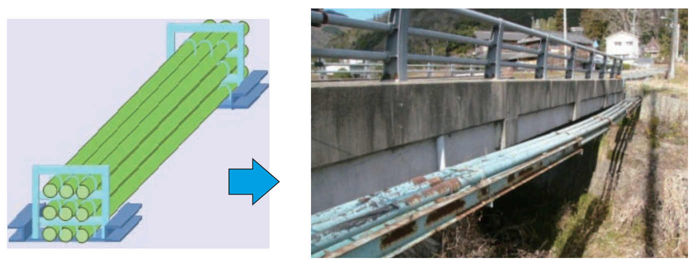


Fig. 3. Images of non-standard private bridges.

various factors that affect the underground environment, for example, loss of strength due to the deterioration of steel pipe, the line *type*, which refers to the characteristics of conduit such as whether it is horizontal curving or longitudinal sloping, or whether protective concrete is used, and the ground conditions where the conduit is located.

2. Earthquake resistance evaluation technology for non-standard private bridges

NTT has constructed and owns two types of private bridges that support telecommunication cables (telecommunication bridges): standard and non-standard. The standard bridges conform to current NTT standards. In contrast, the non-standard bridges are bridges that conform to old standards or that were devised and constructed individually according to on-site conditions. There are two broad types of non-standard private bridges (**Fig. 3**).

Standard private bridges have been evaluated for earthquake resistance; however, the structure of non-standard private bridges differs greatly from ordinary bridges, and hence, their behavior during an earthquake is not clear. Private bridges are laid across rivers and carry assorted cables used to provide telecommunication services. A failure in one of these bridges would affect third parties such as pedestrians, cars, or vessels traveling on or under the bridge. Although there have been no incidents of bridge failures in past earthquakes, adequate construction and maintenance techniques are necessary because these bridges are important facilities for ensuring network reliability and safety. For this reason, we have been investigating the conditions under which damage occurs and clarifying the damage mechanism during earthquakes by investigating the vibration characteristics and structural analyses of existing facilities [3].

The factors relevant to earthquake damage that may affect bridges fall into two broad types: (i) the inertial force from vibration caused by the earthquake and (ii) collapse of the bridge abutments or the main bridge structure due to liquefaction of the ground that supports the bridge. We have developed technology for understanding the effects of these factors using easily obtained data. The process used to evaluate earthquake resistance is illustrated in **Fig. 4**.

2.1 Evaluation of earthquake vibration

We have clarified the vibration movement of non-standard private bridges by investigating actual non-standard bridges and analyzing the results. We then used the results to create a chart for comparing the inertial forces generated by earthquake motion to the resistance of the steel materials used in the bridges based on simple data such as the length of the bridge

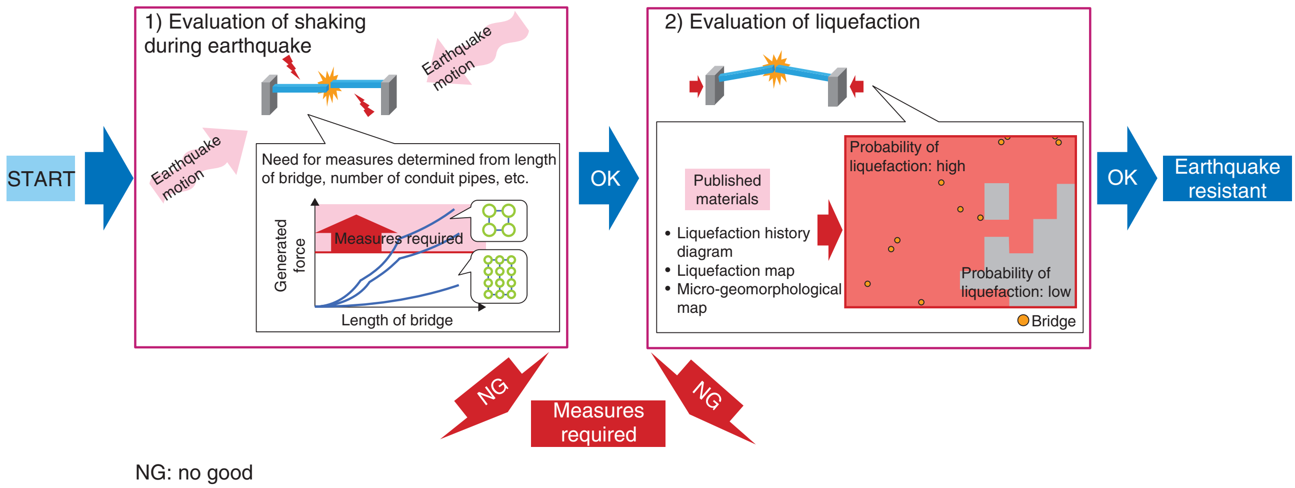


Fig. 4. Process to evaluate earthquake resistance.

and the number of conduit pipes. For bridges without beams, which are one type of non-standard private bridge, we found that the possibility of damage can be determined from the length alone.

2.2 Evaluation of liquefaction

Non-standard private bridges that do not have strong abutments are susceptible to collapse due to liquefaction of the surrounding ground. Therefore, such bridges that are located in areas where the risk of liquefaction is high are classified as requiring improvements. We also created a procedure for determining liquefaction areas using data published by local governments or research organizations. Previously, the determination of liquefaction was based on time-consuming studies that required the collection of geotechnical boring data in the vicinity of the facility. However, liquefaction can be determined by a procedure that effectively uses liquefaction history diagrams, liquefaction maps that record the value of the potential of liquefaction, micro-geomorphological maps, and other published data, thus making it possible to determine the risk of liquefaction for a particular area.

These two evaluation processes enabled us to identify non-standard private bridges that are at high risk of damage and that consequently need immediate countermeasures.

3. Improving earthquake resistance evaluation technology

3.1 Factoring in deterioration of underground conduit

Estimating the damage to underground conduit during an earthquake was previously done assuming that the conduit was sound before the earthquake. Actually, however, a lot of conduit has been in place for over 30 years and may therefore be partially corroded in some areas, and corroded steel conduit is more likely to be weaker than sound conduit. To more accurately determine the location where damage may potentially occur, it is necessary to know the location of weakened conduit and also to what extent the performance of such conduit has decreased. For that purpose, we conducted performance tests on collected conduit pipes that were removed in construction work throughout the country (**Fig. 5**) to determine the degree of deterioration.

The results of the performance testing showed that, on average, the formerly buried conduit performed at roughly 90% of the level of sound conduit, which is to say that the average loss of strength was 10%. However, there was a large dispersion in the values for individual samples, and many samples performed as well as sound pipes. More detailed observations revealed that although there were some exceptions, the performance tended to decrease when there was severe corrosion on the inner surface (**Fig. 6**). We are currently at the stage of confirming the results qualitatively, but in the future, we plan to develop technology

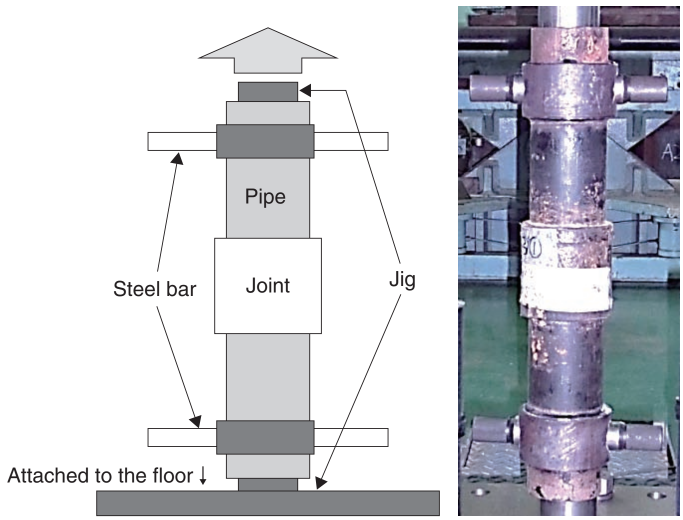


Fig. 5. Performance test (tension test) of conduit pipe.

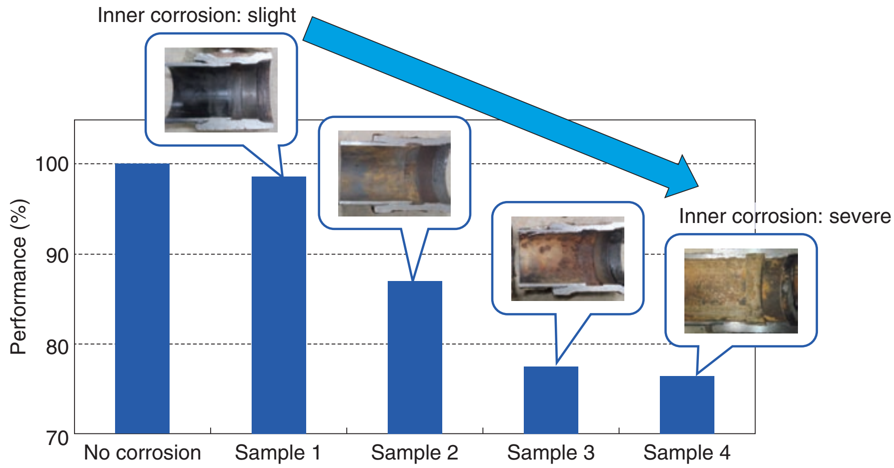


Fig. 6. Examples of inner corrosion and loss of strength.

for predicting the decrease in performance of individual conduits by conducting more basic tests and on-site investigations to reveal the relation of loss of strength to the length of time the conduit has been underground and the ground environment of the conduit.

3.2 Factoring in the line type of underground conduit

NTT underground conduit pipes follow the paths of roads and may deviate from a straight line vertically or horizontally to avoid other buried objects. External forces due to earthquakes may be concentrated at such deviations, making those locations weak points. Some conduit is buried at shallow depths, and the inner cable is protected from construction such as road excavation by concrete that is poured around the conduit. (Since 2003, a protective cover made from recycled optical fiber has been used instead of concrete.) In such locations, the conduit characteristics are discontinuous because the conduit is partially contained within protective concrete, and earthquake forces may be concentrated in those places, creating weak points.

Table 1. Results of damage rate analysis by type of installation.

	Inspected spans	Damaged spans	Damage rate
Total	1064	82	7.7%
Curved	61 (estimated)	6	9.8%
Sloping	Unknown	56	Unknown
With protective concrete	100 (estimated)	22	22%

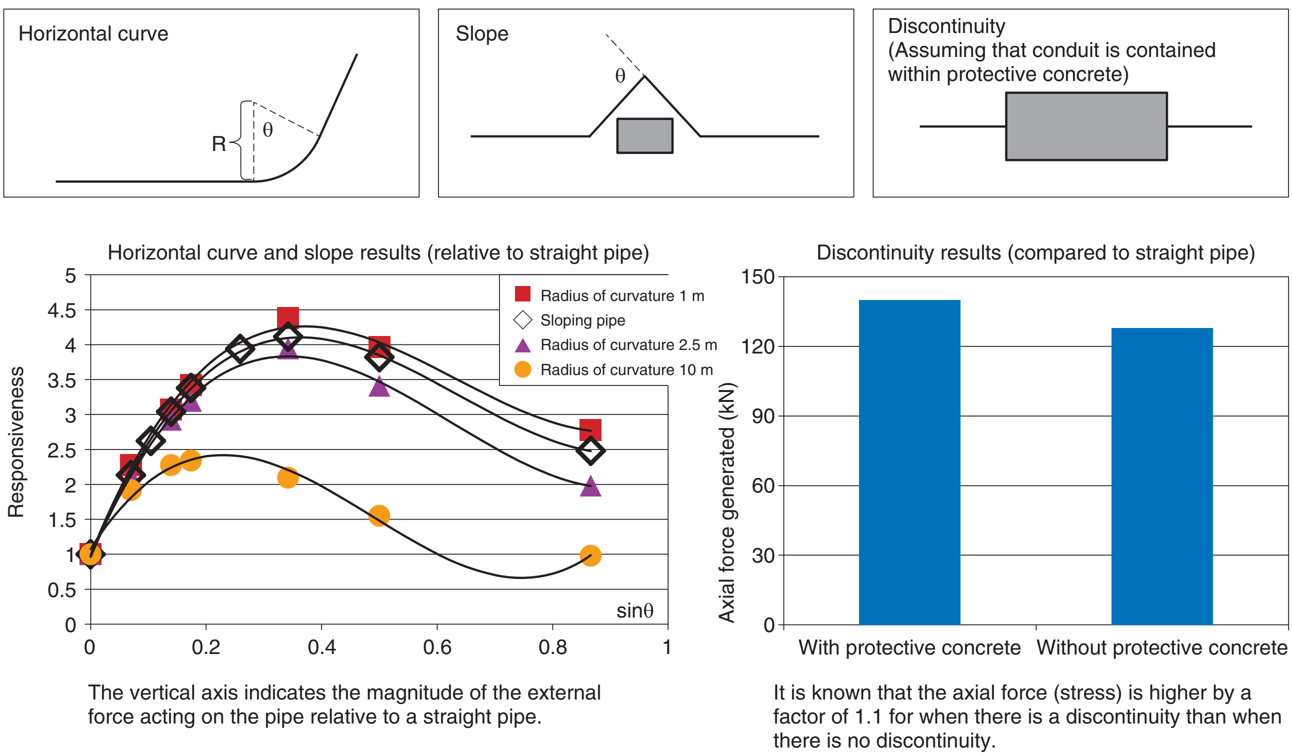


Fig. 7. Analysis models and results.

Past studies of earthquake resistance conducted by NTT did not consider such changes in linearity; thus, the NTT Access Network Service Systems Laboratories is now investigating the susceptibility of such sites to earthquake damage.

An investigation of damaged conduit was conducted after the Great East Japan Earthquake in 2011. The investigation was limited to underground steel pipe sections, so conduit that was located above ground, such as conduit attached to bridges, was excluded. The results are listed in **Table 1**.

The investigation revealed relatively high damage rates for facilities that had protective concrete within the span (higher than the overall rate by a factor of 2.8) and for curved facilities with a radius of curvature of 100 m or less (higher by a factor of 1.3). To quantify the susceptibility to damage, three types of conduit lines—curved conduit, conduit laid on a slope or gradient, and conduit enclosed in protective concrete (referred to as a *discontinuity*)—were modeled, and a numerical analysis was executed. By comparing the results with the analysis results for straight conduit with no linear deviations, we were able to evaluate the effects of the line type of conduit during a large-scale earthquake. The results are shown in **Fig. 7**. Compared to the external force applied on straight conduit, the force is up to 3.5 times higher for curved installations and up to 4 times higher for sloping conduit. With protective concrete, the force is about 1.1 times that of conduit without

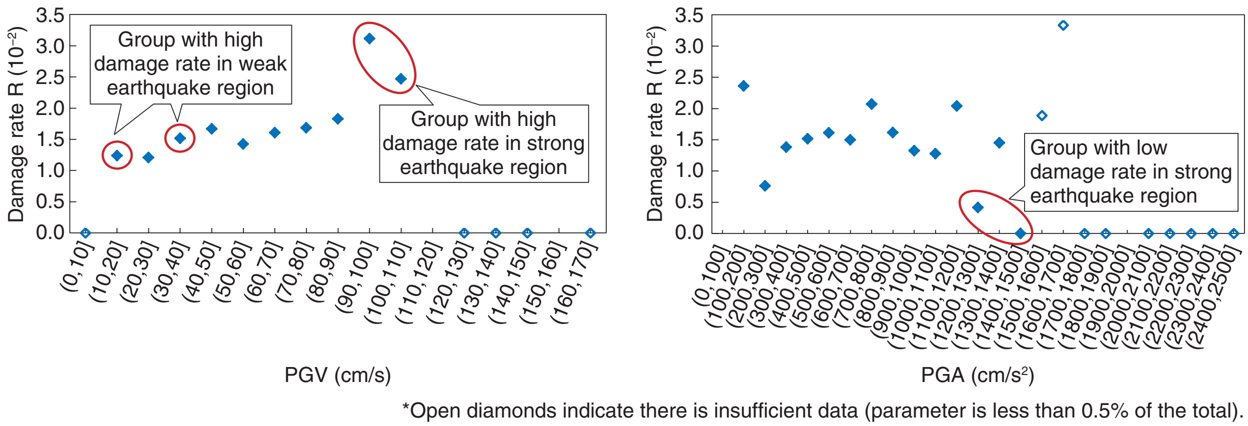


Fig. 8. Results of analyzing underground conduit damage.

protective concrete. Although the analysis is very simple, and more detailed model settings and numerical analyses are required, we can nevertheless identify which types of conduit may have weak points during a large-scale earthquake. In the future, we will conduct a numerical analysis using more detailed conduit models.

3.3 Factoring in the ground environment of underground conduit

In this section, we describe how the ground conditions affect the estimation of damage to conduit during an earthquake. For example, the liquefaction phenomenon was responsible for many incidents of damage that occurred to NTT conduit during the Great East Japan Earthquake in 2011. To quantify the effects of the ground environment on damage, NTT Access Network Service Systems Laboratories performed analyses using ground data and facilities data.

The ground data used in the analysis were earthquake magnitude, peak ground velocity (PGV), and geomorphological classification (e.g., whether it was reclaimed land).

The facilities data used for the analysis included data on a few hundred spans for which damage was confirmed and approximately 20,000 spans for which there was no damage.

A geographic information system (GIS) was used in the analysis to investigate the correlation between the ground conditions and damage. The damage ratio was calculated by focusing on the facility attributes such as the age or type of pipe, the magnitude of the earthquake, and the ground conditions. The results are shown in **Fig. 8**.

The group of conduit pipes in regions where strong earthquakes occurred had a high damage rate, and the group subjected to earthquake motion with a PGV of 90 cm/s or more in particular had a damage rate of about 3%, which is high compared to the other groups. Closer examination of this group revealed that a lot of the damaged conduit in the group was buried in ground whose micro-geomorphological class is *backswamp*, which is generally weak ground, and a lot of the damaged conduit was a type that was introduced prior to the current standards. In other words, the analysis revealed that old standard conduit in weak ground has a high damage rate.

A group with a low damage rate was also confirmed, even though the samples in this group were located in regions where strong earthquakes had occurred. The PGA (peak ground acceleration) was about 1400 cm/s^2, and the damage rate in that group was 0.5%, which is lower than in other groups. Most of the conduit in that group was constructed based on current standards. These results indicate that the current standards for earthquake resistance are superior to the former standards.

In contrast, a group of conduit that exhibited a damage rate of 1% in weak earthquake regions where the PGV was around 30 cm/s was also confirmed. This value is about the same as the damage rates of other groups subjected to strong earthquake motion. An examination of the feature attributes of that group revealed that in many cases, the conduit conformed to the old standards and was buried in reclaimed land. In other words, the damage rate was high for old standard conduit buried in areas where liquefaction occurred.

The three tendencies concerning ground environment described here are the same as previous qualitative conditions under which conduit was found to be susceptible to damage during earthquakes in previous qualitative studies. Nevertheless, these results can be considered important for improving the prediction of earthquake damage on the basis of data on underground facilities and the ground environment.

4. Future development

Various factors other than the need to implement earthquake resistance measures may lead to updating of the telecommunication infrastructure. These include aging of facilities, insufficient capacity of facilities, eliminating redundancy in relay cable routes, economizing construction work done by other companies or done collaboratively, and rerouting. It is necessary to implement measures that combine these factors. The technology reported here has contributed to the improved reliability of important telecommunication routes by identifying the weak points that are most likely to be damaged in earthquakes.

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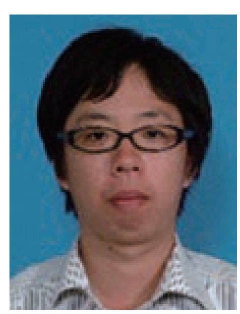

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Technology for Highly Efficient and High Quality Diagnosis of Infrastructure Facilities

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Abstract

The large number of infrastructure facilities throughout the country must be regularly inspected and diagnosed for possible problems. The NTT Access Network Service Systems Laboratories is working toward a transition from the current methods involving inspection and diagnosis by humans to automatic methods, which will be essential for carrying out such work efficiently over a wide area. This work involves advancing the existing image processing technology through a fusion of various technologies that include sensor networks, mechatronics, and remote sensing systems that have been developed in other laboratories. This article describes the inspection technology for concrete utility poles and manhole covers as representative of the direction of our most recent research and development.

Keywords: infrastructure facilities, non-destructive inspection technology, automatic diagnosis

1. Introduction

NTT performs systematic inspections of all facilities, and most of these inspections are done visually. The inspectors observe the infrastructure facilities (for example, concrete utility poles and manholes) that support telecommunications services to see whether any deterioration (such as degradation of performance over time due to corrosion of steel and neutralization of concrete) or deformation (cracking, warping, distortion, peeling, rust run-off, and other abnormalities that can be seen on the surface) has occurred and to determine the degree and scale of the deterioration. The necessary repair, reinforcement, or renovation is then performed. Also, the large amount of data obtained in the inspections is stored in a database and used as evaluation criteria and as a basis for optimizing and adjusting evaluation methods and operations in the maintenance and management of infrastructure facilities. Through such efforts, we ensure the safety and reliability of the many NTT facilities throughout the country and support stable provision of telecommunication services.

Nevertheless, there are problems that must be overcome by introducing new technology for the inspection and diagnosis of infrastructure facilities. These problems include the following:

- The aging of NTT infrastructure facilities results in the need for more frequent inspections and inspection of more items, which increases inspection costs.
- As the baby boom generation retires, the number of proficient technicians with experience and expertise in conducting inspections is declining, so the quality of inspection work done by successor technicians must be maintained and improved.
- The state of degradation must be determined in order to facilitate renovation and extension of service life of the underground tunnels that

- house a large quantity of telecommunication cables and extend for several dozen kilometers, and the manholes for accessing facilities buried beneath roads.
- There is a strong social need to preserve the safety of the aging social infrastructure, as well as the structures managed by local and national governments (bridges, tunnels, roads, manholes, and other ancillary road structures) and the facilities that depend on them (such as the conduits supported by bridges). The consequent trend toward obligatory periodic inspections results in a significant amount of inspection work and a high inspection cost.

The NTT Access Network Service Systems Laboratories took these problems into account and focused on the three aspects of cost, quality, and added value in creating new inspection technology. For cost, we targeted inspection methods that involve less work, fewer procedures, and fewer people. For quality, we aimed to develop inspection methods that could be done accurately and uniformly by anyone, anywhere, and at any time, without requiring the skill level of an experienced technician. For added value, our objectives were ease of handling, higher work safety, and visualization techniques for locations where naked-eye inspections are difficult.

The research being done at the NTT Access Network Service Systems Laboratories on infrastructure facilities inspection and diagnosis technology is moving forward, with short-to-mid-term work and long-term work being done in parallel.

Our short-term to mid-term work puts priority on maintaining safety with respect to inspection of infrastructure facilities (concrete poles, manhole covers, and facilities attached to bridges) in which there is potential for damage or harm to third parties. Specifically, we aim to develop inspection and diagnosis technology that eliminates sites where inspection is difficult or impossible and that reduces the number of sites where high levels of labor, cost, and technical skills are required. Our mid-term to long-term work is aimed at developing innovative inspection and diagnosis technology that achieves a radical change in the maintenance and management of infrastructure facilities through collaboration with other NTT laboratories developing image processing technology and sensor technology to enable screening inspection and continuous monitoring using still and moving images.

This article describes the direction of the most recent research on infrastructure facility inspection and diagnosis for concrete poles and manhole covers underway at the NTT Access Network Service Systems Laboratories.

2. Concrete pole inspection and diagnosis technology

NTT EAST and NTT WEST together have about eight million concrete poles throughout Japan, which are inspected periodically to maintain them in a safe condition. In the inspections, the surface is examined for cracks by eyesight or with a binocular microscope. Ultrasound sensors are used for non-destructive inspection of parts that are underground or that are hidden by sheets attached to the poles to prevent the posting of advertisements, and magnetic sensors are used to check the utility pole for internal degradation. An accurate understanding of cracking or internal degradation, however, requires inspectors that have expert knowledge, skill, and proficiency. Recently, the number of proficient technicians available for inspecting concrete poles that are in service has been decreasing, making it difficult to maintain both the quantity and quality of inspections. To address this problem, the NTT Access Network Service Systems Laboratories has been researching three inspection and diagnosis technologies for utility poles. These technologies enable inspections that are even more accurate and efficient than current inspections regardless of the skill and proficiency of the inspector.

2.1 Crack inspection technology based on image analysis

This technology can automatically detect the cracks that arise on the surface of concrete poles from photographic images obtained with commercially available digital cameras (**Fig. 1**). However, remotely acquired photographs of concrete poles often include cables, foot pegs, and other objects attached to the poles, as well as the area in the background, so the outline edges of those objects may be mistakenly detected as cracks in the image processing. Humans use information such as hue and the feel of a material to recognize cracks on the surface of a concrete pole, so we have implemented a function for automatically removing attached objects and the background from the image by implementing this discrimination task using image processing technology. By doing so, we were able to reduce errors in detection and to accurately detect cracks. This technology can be used to conduct accurate inspections, regardless of worker skill and experience, and it makes it easy to check for

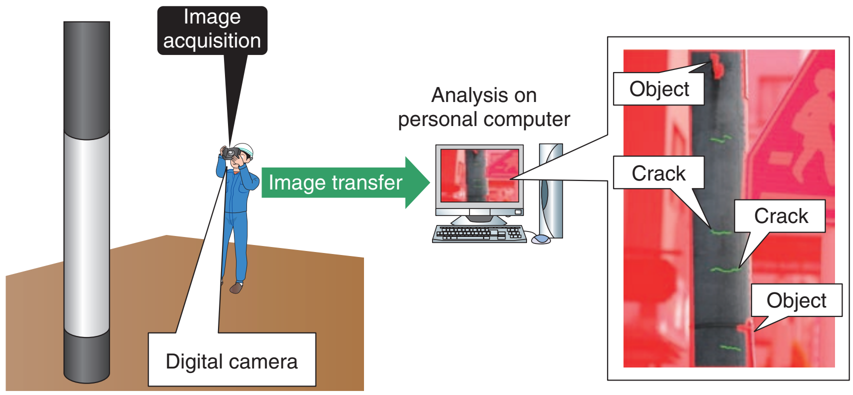

Fig. 1. Detection of cracks by image analysis.

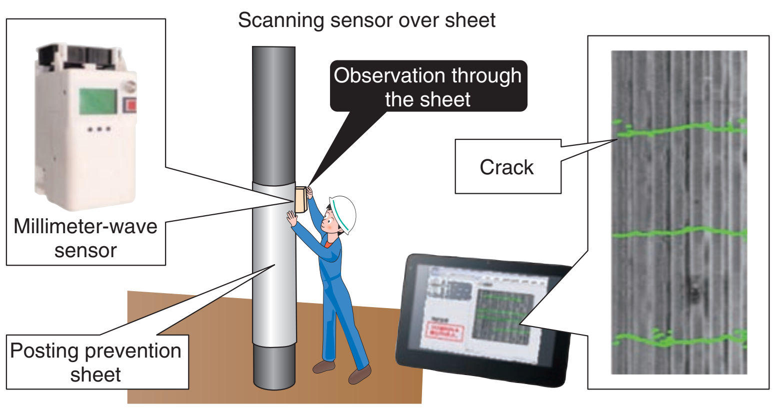

Fig. 2. Detection of cracks beneath protective sheet by millimeter-wave see-through imaging.

the presence of cracks and their location, including on the upper parts of concrete poles, which previously required extensive labor for visual inspection. There is also a function for automatically organizing and managing the large number of acquired images for each utility pole, which greatly reduces the amount of paperwork.

2.2 Technology for detecting cracks beneath protective sheets

Currently, the detection of cracks hidden behind posting prevention sheets and other obstacles is done with detection equipment that uses ultrasound. However, some expertise is required to read the propagated waveforms with this technique, so the inspectors must have the appropriate skills. To solve this problem, we developed the world's first equipment for conducting inspections for cracks beneath posting prevention sheets with imaging technology that uses millimeter waves* in the 76.5-GHz band, at which the sheeting is transparent (**Fig. 2**).

In this technique, the surface of a utility pole is illuminated with millimeter waves. Places on the surface where there are no cracks reflect the waves back with a certain strength, but places where there are cracks disperse the reflected waves in all directions, so the strength of the waves reflected back toward the source (backscattering) is detected as a small signal. Because the posting prevention sheets are transparent to millimeter waves, and the waves are reflected by the concrete surface, we are able to implement the see-through imaging of cracks. The crack inspection

* Millimeter wave: An electromagnetic frequency band extending from 30 GHz to 300 GHz. The short wavelengths make this band intermediate between light and radio waves.

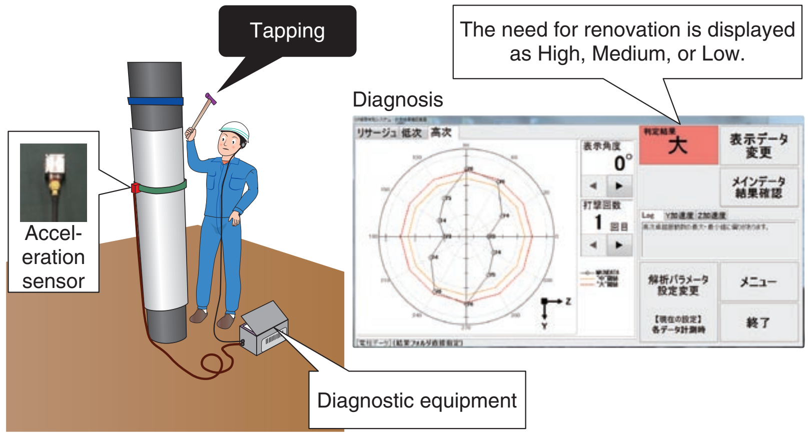

Fig. 3. Diagnosis of soundness by vibration analysis.

system we constructed creates a see-through image from the signals detected from the concrete surface, and software included in the system automatically identifies cracks from the image. It is thus possible to check for cracks visually without relying on inspector skill or proficiency.

2.3 Soundness diagnosis technology

Currently, when cracks are discovered in a concrete pole, magnetic sensors are used to perform a detailed examination to determine the condition of the rebar inside the pole. That method, however, requires a special work vehicle to access the upper part of the pole so that the pole can be scanned, and the measurement requires time and labor. We therefore developed a soundness diagnosis technique that enables an inspector on the ground to diagnose soundness by simply striking the side of the utility pole with a hammer (**Fig. 3**). The inspector taps the utility pole around the circumference with the hammer, and the resulting vibrations are measured. If the utility pole is sound, the measurements will be uniform around the circumference. If there is a defect or other problem, the rigidity will not be uniform, and the frequencies of vibrations measured from striking the pole at certain places around the pole will vary. The soundness of a pole can therefore be determined by variations in the natural frequency in response to tapping around the pole circumference.

The three technologies described above are already being used for some of the concrete poles managed by NTT, and we plan to proceed with their commercial introduction in order to maintain and manage facility safety.

3. Technology for measuring level differences in manhole covers

NTT maintains about 680,000 manholes throughout Japan, and the manhole covers are inspected periodically to see if there is a difference in level between the manhole cover and the seat it fits into. If there is an excess level difference between the manhole cover and the frame, it could result in an uncomfortable and noisy ride for vehicles driving over the manhole cover. The current method of measuring the level difference involves the inspector setting up safety barriers on the road and then using a vernier caliper or other tool to take the measurement while continuing to check for safe conditions (**Fig. 4**). This method is problematic in that it is necessary to apply for a permit before conducting the on-site inspection, safety barriers must be set up to ensure the safety of the inspector, and local traffic is affected for the duration of the inspection. To address these problems, the NTT Access Network Service Systems Laboratories developed image-based level difference measurement technology with the objective of achieving a safe and efficient method for inspecting manhole covers.

That technology involves using a commercially available single-lens reflex camera to acquire images of manhole covers. From the images, areas where level differences exist are identified, and the level differences are measured. An advantage of this method is that the inspection can be done from a distance. The inspector photographs the manhole cover from the sidewalk or another safe location with a digital camera, and the acquired image data are transferred to a

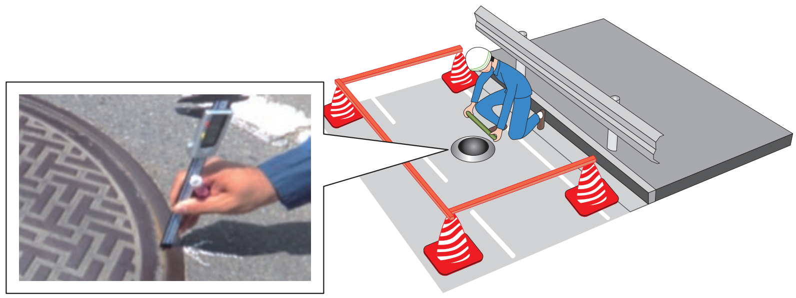

Fig. 4. Current method used to measure level differences.

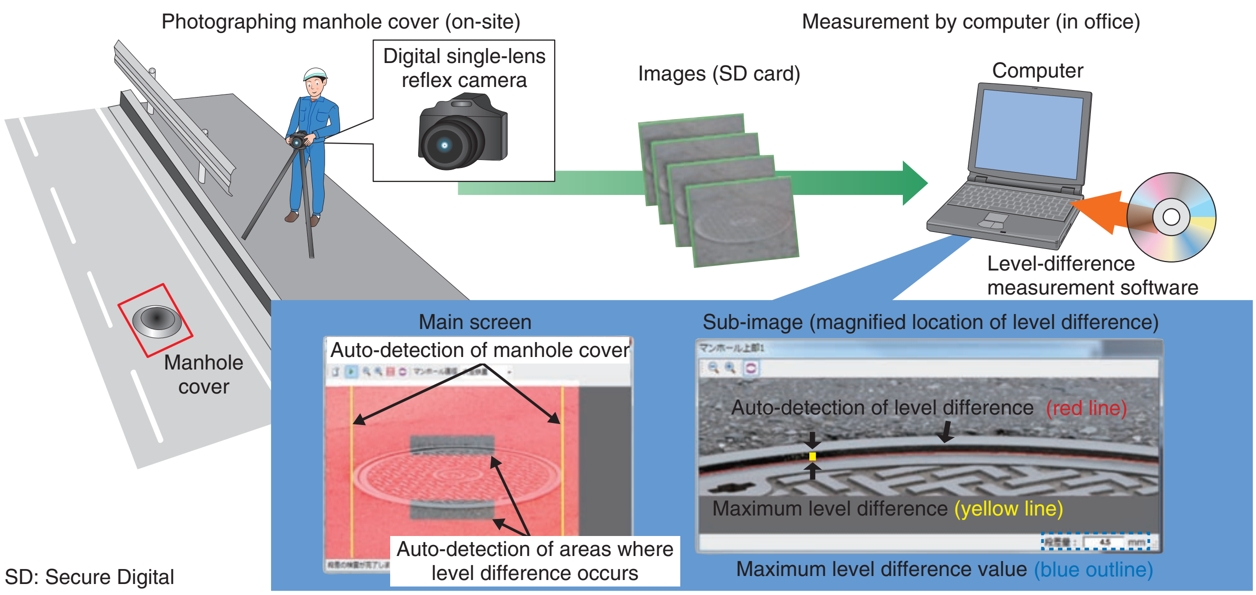

Fig. 5. Measurement of level difference from image acquired by digital single-lens reflex camera.

computer and stored (**Fig. 5**). Level-difference measurement software is then used to automatically detect the areas in which there is a difference in level between the manhole cover and the frame in which the cover sits. The detected areas and the maximum differences in level are displayed on the screen. Actual images contain curbs, road marking lines, gravel, grass, and other irrelevant objects, but those objects can be appropriately eliminated by a new function that uses texture and color information, thus reducing detection errors. This technology makes it possible to measure level differences in manhole covers by simply taking a photograph from a safe location. We plan to begin implementing this technology in manhole inspection work performed by NTT in 2014.

4. Future development

We plan to investigate expansion of the use of automatic inspection technology that grew from the development of utility pole inspection and diagnosis technology to manholes, tunnels, and other concrete structures. Our objective is to apply this technology broadly so that inspection work can be done safely and without worry, and inspection costs can be reduced for all NTT infrastructure facilities. For the inspection of manhole covers, we are also planning to conduct research on automatic inspection technology that applies the image processing technology produced within the NTT laboratories to measure the state of surface wear—another important maintenance item—from images. Establishing technology for simultaneous inspection of level differences and wear of steel manhole covers from photographs is expected to greatly reduce the work required for manhole cover inspection and to make such inspections easier. We also plan to investigate automated inspection technology for facilities that are attached to bridges.

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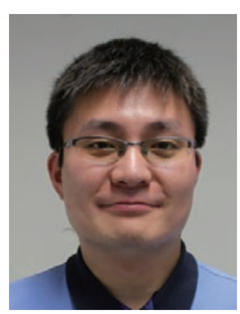

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Repair and Reinforcement Technology for Safe and Secure Concrete Structures that Have a Long Service Life

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Abstract

A vast number of concrete manhole and tunnel structures managed by NTT are 30–40 years old, and there is obvious degradation in some of those facilities. To address this problem, the NTT Access Network Service Systems Laboratories has been conducting research and development on the technology needed to extend facility use long into the future, including technology for more efficient and cost-effective maintenance and management, accurate measurement of the durability of existing facilities, and effective and economical repair and reinforcement. This article describes the direction and future development of that work.

Keywords: concrete structures, durability evaluation, repair and reinforcement

1. Research and development (R&D) on manhole maintenance and management

1.1 Current state of maintenance and management

NTT has about 680,000 manholes throughout Japan (**Fig. 1**). They serve as connection points for telecommunication cables and hubs for customer lead-in cables, and they also provide space for maintenance work. The majority of manhole facilities were constructed from 30 to 40 years ago or earlier, and degradation such as concrete cracking, concrete separation, and rebar exposure has become evident in recent years. Currently, only 6% of all manhole facilities have been determined to be degraded (**Fig. 2**); however, a significant number of this group are affected by rebar corrosion and require repair or reinforcement (**Fig. 3**). The cost of repairs is expected to increase as these facilities continue to age.

Because manholes are buried at relatively shallow depths of from several tens of centimeters to several meters below the surface of roads, they are susceptible to effects from the weight of vehicles (live load). There was a large increase in live load with the expansion of goods distribution that followed the period of high economic growth when many of the manholes were constructed. As a result, even though the facilities were designed to have sufficient strength, some were subjected to loads beyond what was assumed at the time of construction.

Accordingly, a method is needed to evaluate durability that appropriately takes into account future aging of facilities and environmental factors such as changes in the live load. Additionally, technology for economical repair and reinforcement that matches the evaluated durability is necessary.

1.2 R&D direction

The two basic types of manhole structures are steel reinforced concrete (about 580,000 in service) and

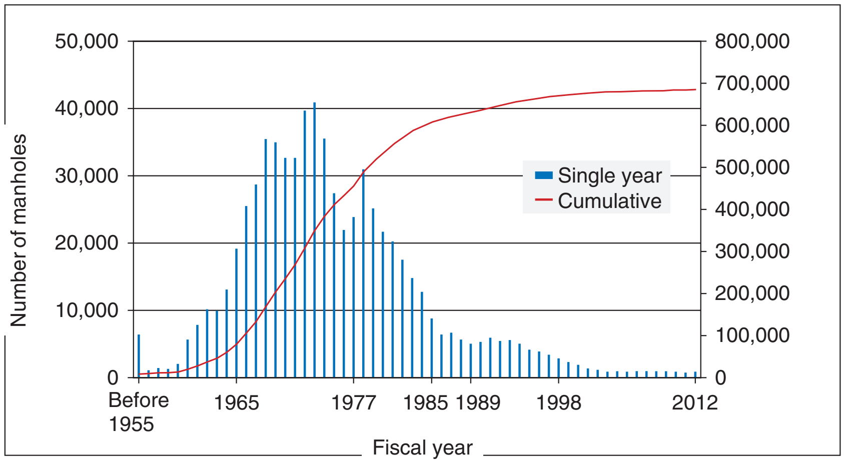

Fig. 1. Number of manholes by age of construction.

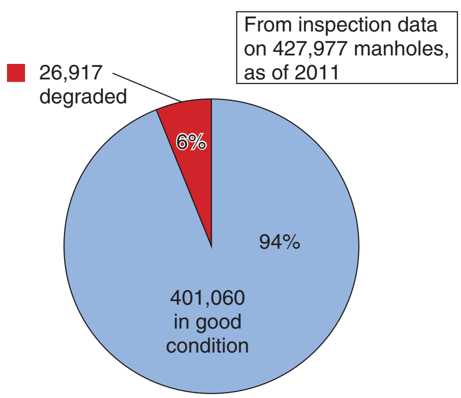

Fig. 2. Number of degraded manholes.

resin block concrete (about 100,000 in service). Resin block concrete manholes are constructed with high-strength resin concrete, and inspection results show there is relatively little degradation of this type. Therefore, in our continuing investigation, we are targeting steel reinforced concrete manholes that have obvious rebar corrosion. A schematic and a photo of a steel reinforced concrete manhole are shown in **Fig. 4**.

The degradation in steel reinforced concrete manholes indicates that rebar exposure that progresses from cracks occurs mainly on the ceiling and is therefore considered to be an effect of the live load on the facility.

Furthermore, the resistance to the live load on the top of the manhole structure is maintained primarily by the rebar, so manhole safety and security requires particular attention to rebar corrosion in the ceiling of the structure.

Manholes can be broadly grouped into the earliest reinforced manholes, which conform to the standards of 1956 and were constructed in a period when traffic was relatively light, (about 430,000 in service), and those that conform to the more stringent 1977 standard (about 250,000 in service). Inspections reveal that manholes in the first group account for a relatively large proportion of the degraded facilities, so we must place priority on that group.

Currently, there are two ranks for degradation, but the degree of degradation actually varies from facility to facility. The method of repair and reinforcement also varies according to the degree of degradation. Thus, a more detailed degradation ranking system is needed to lower the repair cost.

Nevertheless, the availability of skilled technicians is expected to continue to decrease into the future, and consequently, appropriate evaluation of the degree of degradation by inspectors, and determination of the optimum repair and reinforcement method are likely to become increasingly difficult.

Therefore, the NTT Access Network Service Systems Laboratories has been developing a simple method that can be applied on-site for evaluation of degradation in the top part of the 1956-standard manholes and a method for setting repair and reinforcement criteria based on the degree of degradation.

Fig. 3.   Types of manhole degradation.

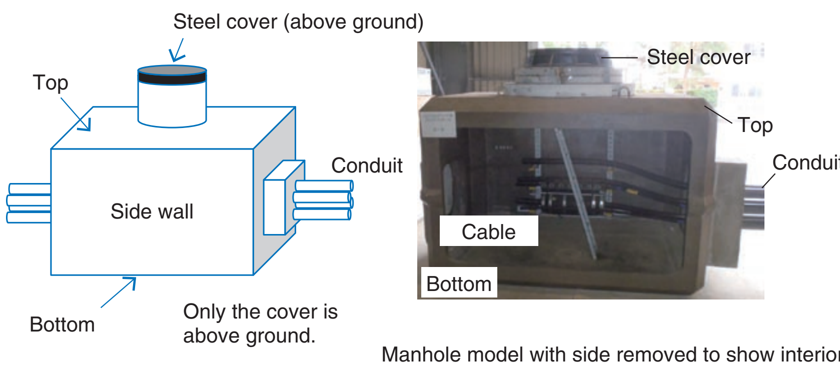

Fig. 4.   Structure of steel reinforced concrete manhole.

1.3 Evaluation methods for manhole maintenance

(1) Evaluation of durability by the degree of degradation

On the basis of the assumption that the strength of the rebar governs the durability of the manhole, we conducted bending strength tests on a beam model of part of the ceiling of a manhole to determine the relation of rebar corrosion to manhole durability. The results showed that the relation of the amount of rebar corrosion to the decrease in durability in ordinary reinforced concrete structures can also be applied to NTT manholes.

As a simple on-site method of evaluating the durability of manholes, which vary in size and depth below ground level, we have also been investigating structural calculations using the known formula regarding the relation of the amount of rebar corrosion to the decrease in durability for ordinary reinforced concrete structures. This approach holds promise as a means of setting the criteria for determining when repair or reinforcement is necessary.

(2) Approach for making appropriate structural calculations for 1956-standard manholes

Road traffic was much lighter when the 1956-standard manholes were built than it is today, so the load on the manholes was considered to be concentrated. Later, however, the amount of traffic increased, and the load on the manholes became more constant and evenly distributed. It thus became necessary to evaluate durability under a distributed load.

A search of the literature for a correction formula for structural calculations that applies the current equally distributed load condition produced a way to do structural calculations for 1956-standard manholes under equally distributed loads. An evaluation of the validity of this approach by a manhole maintenance study group in 2013 showed good prospects for applicability.

Currently, we are developing a simple calculation formula that we plan to test in the laboratory with the objective of establishing a simple, on-site evaluation method.

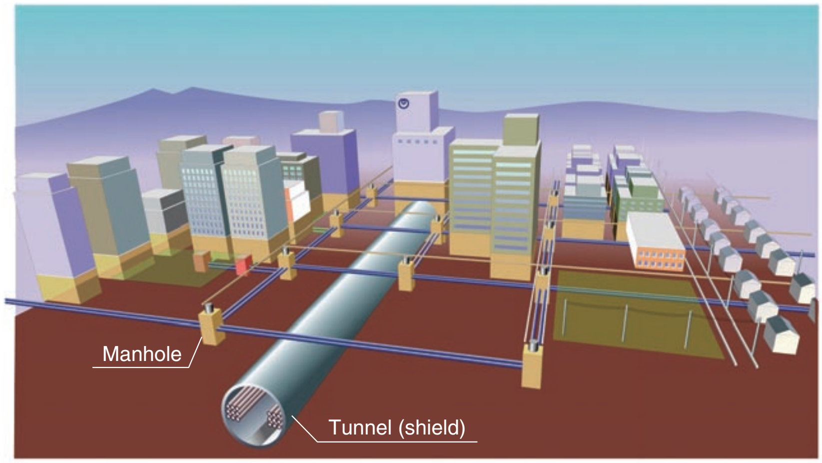

Fig. 5. Tunnel facilities.

1.4 Future development

Although degradation has been confirmed in only a small percentage of manholes, it will continue, and increased degradation is a concern. Because the manholes are buried beneath roads, renovation is not a simple matter, and we must rely on enhanced maintenance and management to extend the service lifetime. Furthermore, maximum efficiency is necessary in determining the present condition of the facilities and dealing with any problems discovered. This is because the approximately 680,000 facilities are scattered across the country, the cost cannot simply be assigned per facility, and the work force is aging. We are currently working on a simple method of evaluating durability based on the degree of degradation without using structural calculations. Future R&D will be aimed at developing reinforcement methods that renovate the degraded concrete and that have long-term effectiveness to extend the service life of the entire manhole facility and achieve higher efficiency in maintenance and management.

2. R&D on tunnel maintenance

2.1 Current state and issues

The deterioration of aging infrastructure facilities is becoming a problem that affects our whole society. Forty years or more have passed since the peak period of NTT telecommunication tunnel construction, and concerns for the future are growing as concrete degradation increases due to the intrusion of underground water and its corrosive effect on rebar.

Tunnels house the large numbers of cable that lead out from telecommunication buildings. In an analogy with the human body, they would correspond to the aorta of the heart. Any problem that arises with the tunnels can affect the entire telecommunication network, so it is crucial to keep these important facilities in good working order (**Fig. 5**).

There are two types of tunnels: cut-and-cover tunnels and shield tunnels. Cut-and-cover tunnels are constructed of steel reinforced concrete and have a rectangular cross section. They are built by excavating to a relatively shallow depth of from 5 to 10 m below the ground surface. Shield tunnels have a circular cross-section and are constructed by boring through the earth at depths from 15 to 30 m underground using a shield tunneling machine (**Fig. 6**).

Tunnels range from several tens of meters to several hundreds of meters in length. There are about 650 km of telecommunication tunnels in Japan in total, mainly in urban areas, and renovation of these facilities is very difficult. Accordingly, maintaining safety over a long service life and curtailing maintenance costs are major issues in maintenance and management.

Cut-and-cover tunnels were constructed in an earlier period than shield tunnels, and degradation such as rebar corrosion and concrete separation has been observed in some of them. Therefore, we have carried out planned maintenance work for the cut-and-cover tunnels by setting priorities. Specifically, we optimize the scope and timing of repair work according to a life cycle cost evaluation based on degradation criteria and prediction of degradation in steel reinforced concrete. That work is founded on an accurate understanding of facility degradation states

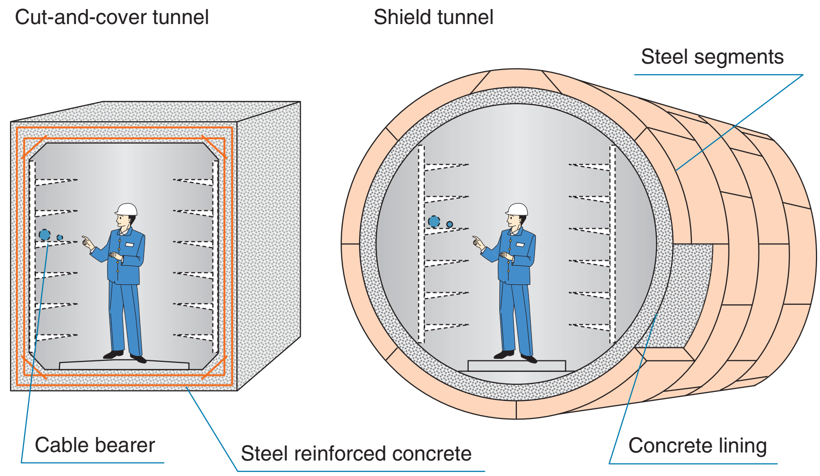

Fig. 6. Types of tunnel structures.

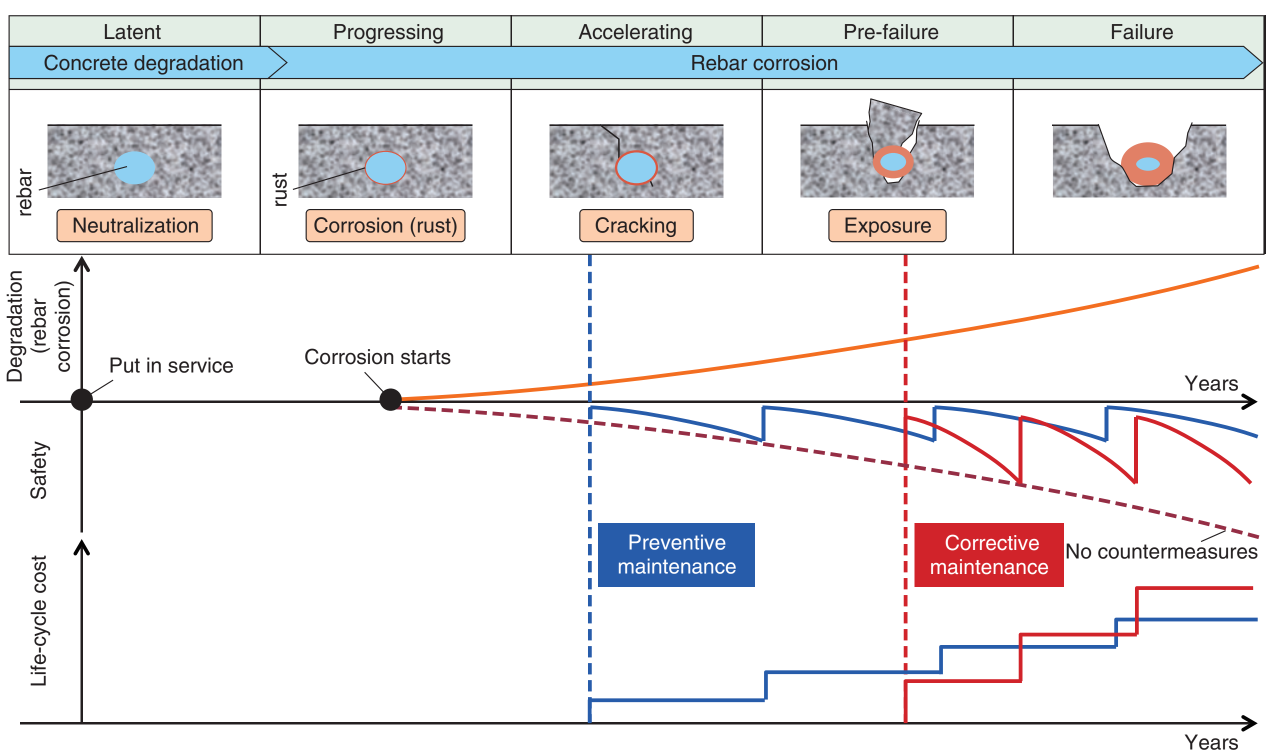

Fig. 7. Optimum repair timing of cut-and-cover tunnels.

obtained using management tools and a periodic inspection database of inspection results (**Fig. 7**).

2.2 Direction of R&D

There are several different types of ordinary shield tunnel structures, but most consist of steel segments and a concrete lining. Other tunnels that have similar structures include some sewage tunnels, although they differ in the materials used and other details, so the structures are not strictly the same. Therefore,

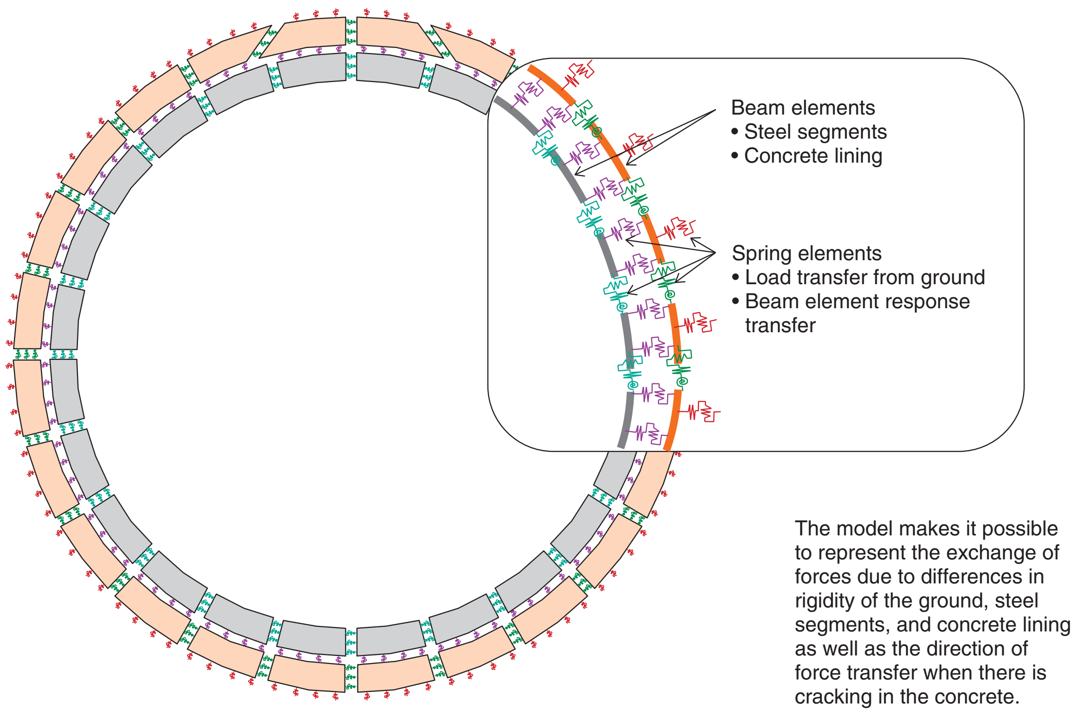

Fig. 8. Beam and spring analysis model.

R&D concerning evaluation of facility durability and repair and reinforcement must be done independently.

NTT telecommunication shield tunnels also have the same basic structure, but they differ in their dimensions and installation environment. Also, the actual constructions of those tunnels were based on individual designs. We have been devising required maintenance measures according to individual designs while managing individual states according to inspection results. Our R&D target, however, is to create a highly general standard method that is based on the basic structure and that can accommodate individual environmental conditions. To deal with the reduced availability of technicians in the future due to the aging work force, we are developing maintenance techniques that can be performed simply and easily by workers who do not require advanced design skills in order to allow the continued safe use of facilities with long inspection intervals and without the need for repeated maintenance.

2.3 Evaluation method for shield tunnel maintenance and management

Shield tunnels are designed to resist loads acting on the structure, for example, soil pressure, by the steel segment alone. The concrete lining is intended to prevent corrosion and seepage of underground water into the tunnel. Conventionally, the durability of completed shield tunnels is evaluated by applying the same design calculation method as that used at the time of construction. However, it became clear in experiments conducted with cross-section models of actual tunnels that the concrete lining also plays a role in durability. That is to say, use of the design calculation method for tunnel construction to evaluate existing shield tunnels may underestimate their durability. Therefore, taking the concrete lining into account in the durability evaluation makes it possible to avoid excessive reinforcement and to maintain safety economically when considering the necessary reinforcement in the event of degradation due to corrosion of steel segments. We have completed the development of this new evaluation method.

The new evaluation method for existing tunnels uses a beam-spring computational model that is used for the cross-sectional influence analysis. We devised an analytical model that can reproduce the responses of steel segments and the concrete lining. That analytical model can also represent the response transfer due to cracks or non-uniformity in the concrete lining (**Fig. 8**).

2.4 Future development

An important future maintenance goal is to reduce the number of facilities that require maintenance. One of our current tasks is to develop a repair method that effectively extends the service life by making it possible to prevent water from coming into shield tunnels over the long term. Water seepage is one of the factors that necessitate frequent repairs. We are also working on a method of reinforcing the strength of degraded parts using a simple and minimum structure.

We intend to continue working on capabilities that are necessary for optimum timing in planned maintenance, including increasing the efficiency of inspection work, applying automation, and improving the accuracy of methods for predicting the progression of corrosion and other forms of degradation. In the future, we will continue to seek an overall picture of an effective tunnel maintenance cycle and to develop the optimum solution for operations.

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Effective Repair and Reinforcement Technology for Conduit Facilities

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Abstract

Conduit facilities are located in every part of the country. As the huge number of conduit facilities deteriorate because of age, the cost of renovation and repair as well as maintenance and management increases, there is concern that network reliability may decline as a result. The development of conduit renewal techniques that use new technology and new materials will enable us to achieve the most effective use of conduit facilities and will contribute to reducing costs and maintaining a highly reliable network. This article describes newly developed maintenance and management technologies for buried conduit and conduit attached to bridges.

Keywords: infrastructure facilities, repair technology, permanence of facilities

1. Introduction

The telecommunication infrastructure supports a wide variety of information and telecommunication services that use telephones and the Internet. Part of that infrastructure consists of about 630,000 km of underground telecommunication conduit managed by NTT, and 70% of that conduit is at least 30 years old. A high proportion of old conduit is made of steel pipe, which has a strong tendency to deteriorate with age, so the number of degraded facilities is expected to increase. While we are continuing to improve facilities based on what we have learned from past major earthquakes, most old conduit was designed on old standards and therefore has low resistance to earthquakes. We must therefore take measures to prevent large-scale damage of these facilities in order to improve network reliability (**Fig. 1**).

Maintaining telecommunication reliability through efficient maintenance and operation of the immense number of aging conduit facilities is a problem in view of the limited resources. For underground conduit, the steadily progressing facility degradation and the on-going transition to optical transmission create concerns about whether there is sufficient space to accommodate underground cables. To address these concerns, we developed and introduced technology for repairing cable conduit that also creates extra cable space and improves resistance to earthquake damage. We are working on applying the technology to more types of conduit and reducing the repair cost.

Steel conduit that is attached to bridges is exposed to various conditions that promote corrosion. These include repeated wet and dry cycles because of rain, being sprayed with anti-freezing agents in winter, exposure to airborne salt in coastal regions, and various other severe environmental conditions. We are currently developing technology for safely cutting cable conduit and replacing degraded conduit with corrosion-free fiber reinforced plastic (FRP) pipe, which we plan to apply to corrosion-degraded conduit attached to bridges. We are also working on technology for reducing OPEX (operating expenses) by preventing the progression of rusting and extending the effective lifetime of coating materials.

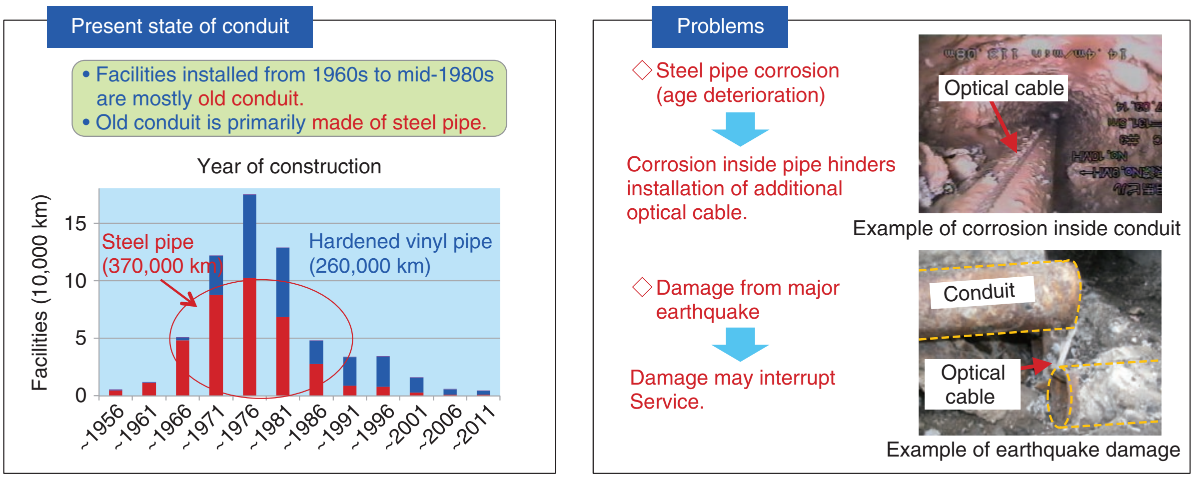


Fig. 1. Current state and problems of conduit.

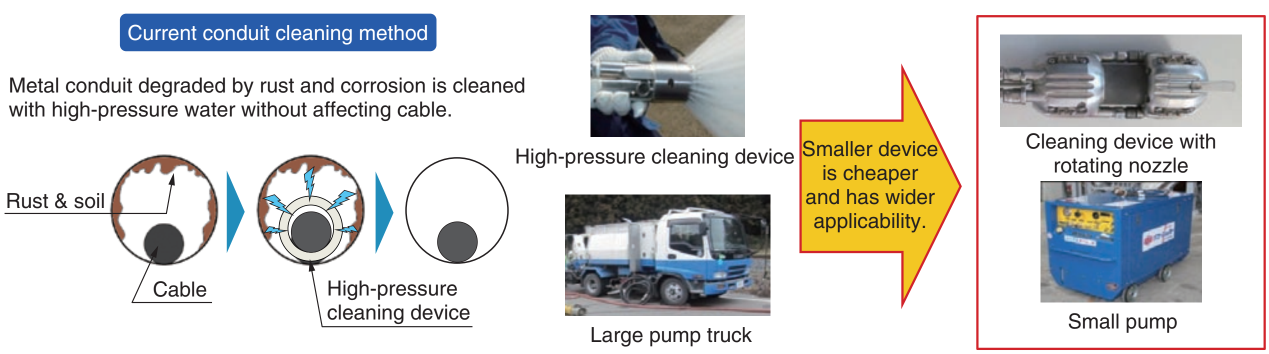


Fig. 2. Current conduit cleaning technology and new cleaning device.

2. Underground conduit repair technology

New optical cable is being laid in the transition to optical transmission, and the use of multiline cable (laying multiple cables in a single conduit) is increasing in order to effectively use the limited underground cable accommodation space. However, about 52% of the conduit for which multiline-cable laying is planned has been diagnosed as degraded by rust or corrosion to an extent that prevents the use of multiline cable. As a result, roads have been excavated to add or reroute conduit, and some conduit has been repaired using the cut-and-cover method.

However, cut-and-cover repairs are expensive and time-consuming. They also cause many environmental problems such as traffic congestion and noise, and they result in excess soil remaining after excavation. Therefore, a different solution is needed. We focused on finding a more effective method to repair steel conduit that contains optical cable and consequently developed technology for removing the rust and corrosion that causes degradation. The technology can be applied while the existing cable remains in place. We also developed conduit repair and rehabilitation technology that has wide applicability. These technologies and their most recent states of development are described in the following sections.

2.1 Technology for cleaning cable conduit

This technology uses high-pressure water to remove rust and corrosion from conduit that contains cable without affecting the cable (**Fig. 2**). An existing technique is capable of cleaning conduit up to 150 m in length. However, it requires a large truck equipped

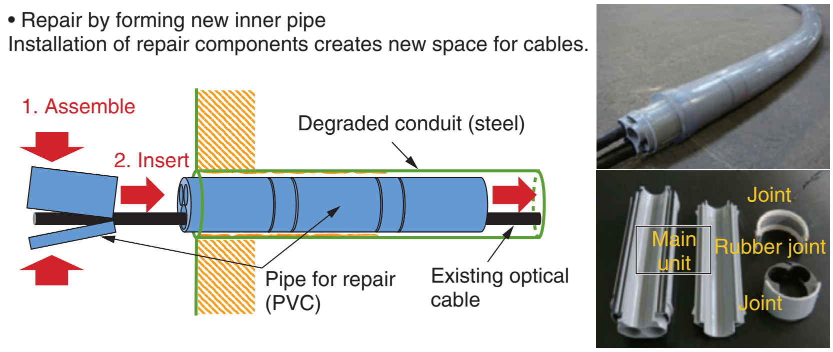


Fig. 3. PIT new conduit repair and renovation method.

with a high-pressure pump that is expensive and has restrictions on how it can be used in construction. To overcome these problems, we developed a compact cleaning unit that can be used for small-diameter conduit and can accomplish the cleaning with a smaller, general-purpose pump. For effective cleaning with a lower pump output, we devised a rotating nozzle that has smaller holes, as shown on the right side of Fig. 2. We also developed a low-friction hose for cleaning longer lengths of pipe. It can safely work at distances of up to 250 m. This technology expands the application range, makes the system more flexible to use, and reduces cost by approximately 30% relative to current methods. The rotating nozzle cleaning head will be introduced in the second half of fiscal year (FY) 2014.

2.2 Technology for repair and rehabilitation of cable conduit

The PIT (pipe insertion type) new conduit method is used to repair conduit that has existing cable in place. It uses components that have an upper part and lower part made of PVC (polyvinyl chloride) and that are assembled around the existing cable. The components are 23 cm long and are connected end-to-end and pressed into the conduit that is being repaired to form a new pipe (**Fig. 3**). The entire conduit that is to be repaired becomes a double pipe, with the pipe formed by the repair component inside the original conduit. Even though the outer steel pipe has degraded with age, the inner repair pipe is strong, so the resulting structure is maintenance free. The repair also has no effect on the existing cable, so there is no interruption of service during the repair. The repair involves no excavation of roads and no open cuts, so it is less expensive and has no negative environmental effects. The repair also creates two new cable accommodation spaces, making a total maximum capacity of 3000 cores (1000 × 3). The double structure created by the repair also increases the resistance to earthquake damage and improves facility reliability.

The PIT new conduit method was first introduced by NTT EAST and NTT WEST in 2012, but its application was limited. For example, the maximum length of conduit that could be repaired was 150 m, and it also could not be used for older, small-diameter conduit. We therefore worked to expand the applicability of the technology.

We reconsidered the component design in order to extend the length of conduit that could be repaired. We also changed the structure so it could better withstand the thrusting force generated when the units are pressed into the conduit being repaired, thus extending the repairable length to 250 m. We also revised the component structure so it could be applied to older, small-diameter conduit. The outside diameter of the modified component is smaller, so the cable accommodation capacity is also smaller. However, the existing cable accommodation space is also smaller, (small-diameter, 1000-core optical cable or less), we were able to make the newly created cable space the same as for current components, thus securing space for 3000 cores (3 small-diameter, 1000-core optical cables). In this way, we expanded the application range of the PIT new conduit method to older, small-diameter conduit. We also confirmed that the new design can withstand earthquake forces just as well as or better than the current vinyl pipe (**Fig. 4**). This technology is planned for commercial introduction in the latter half of FY2014.

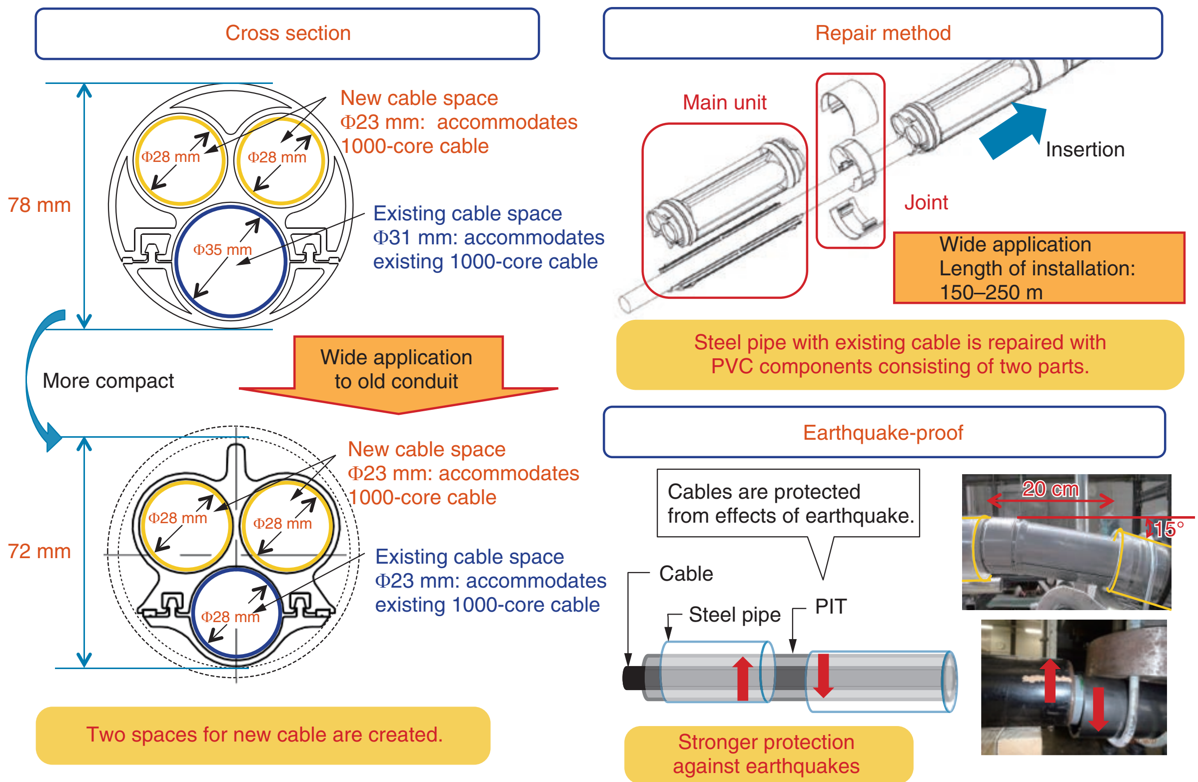


Fig. 4. Advantages of PIT new conduit method.

Fig. 5. NTT bridge facilities.

3. Technology for repairing conduit attached to bridges

NTT's approximately 50,000 bridge facilities include conduit attached to bridges, special-purpose telecommunication bridges, and pipe bridges (**Fig. 5**). About 20% of these bridge facilities require repairs. Those that have advanced deterioration due to age are being repaired by replacing the conduit, and those that have surface rusting are being repainted. The current replacement repair technique is limited in the length of conduit that can be replaced due to the insufficient strength of FRP pipe. Also, when the gap between conduits is small, there are places where the conduit cannot be cut. We are therefore working on ways of expanding the range of applications of this technique.

The conduit coating technology we are currently

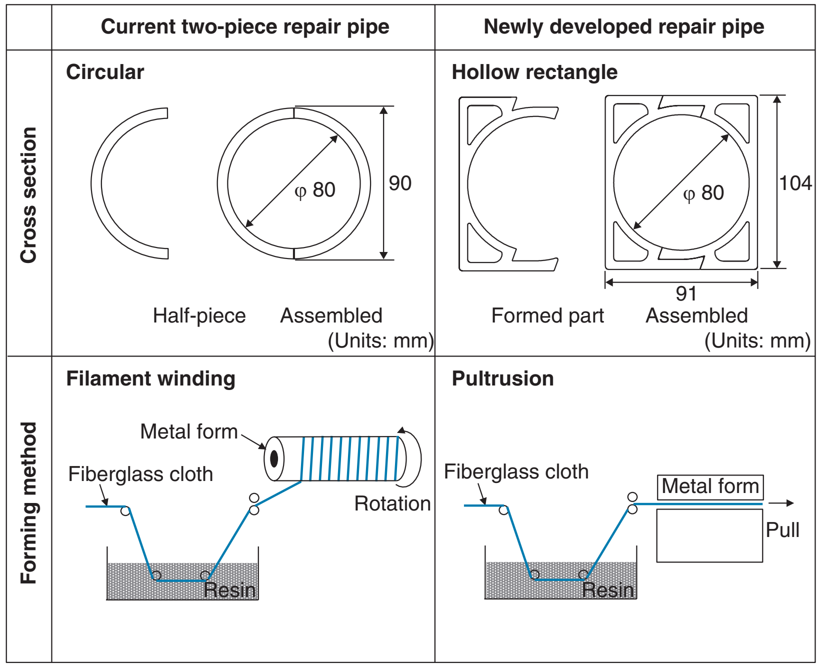


Fig. 6. Comparison of repair pipe structures and forming methods.

using involves the use of an economical and commercially available coating technique. However, this technique cannot keep up with the increasing quantity of age-degraded conduit, so we are developing technology for greatly extending the service life of conduit coatings. These technologies are described below.

3.1 Replacement-repair technology

The replacement technique to repair corrosion-degraded cable conduit attached to bridges involves replacing the corroded section of the steel pipe with two-piece FRP repair pipe. This technique was introduced commercially in FY2008. However, the application of this technique was limited to conduit where the distance between supports was $L = 2.5$ m or less. The main reason for this restriction is that the rigidity of the currently used two-piece repair pipe is insufficient to satisfy the permissible deflection ($L/300$ or less) under load (cable and snow). Applying the current technology with additional supports deviates from the original bridge design, so it is often not possible to obtain permission to modify the structure from the road managing authority, and such repairs then cannot be done.

To solve this problem, we developed long and highly rigid FRP repair pipe that can be used to extend the replacement-repair technique to cable conduit where the distance between supports (L) is up to 5.5 m. The current repair pipe has a circular cross section and is formed by the filament winding method, in which fiberglass cloth is wrapped circumferentially. However, the cross-section shape and material rigidity of this method does not provide sufficient strength for repairs longer than $L = 2.5$ m, as described above. Furthermore, a process for splitting the formed pipe into two pieces is required, which adds to the manufacturing cost. By developing a repair pipe that has a hollow rectangular cross section, we efficiently increased the cross-sectional rigidity. This new repair pipe is formed by pulling fiberglass cloth out in the axial direction of the pipe, thus increasing the material rigidity against perpendicular loads. This is called the *pultrusion* method, and it can be applied to any cross-section shape, so formed parts that have left-right symmetry can be assembled into repair pipe, thus eliminating the splitting process and reducing the manufacturing cost (**Fig. 6**).

This repair pipe is strong and highly resistant to bending and degradation. It is called *ST-LONG pipe*, which is derived from *square-type*, *long length* FRP pipe. Also, to reduce the splitting cost, we adopted the pultrusion method for the insertion sockets, which are used for joining ST-LONG pipe and existing steel

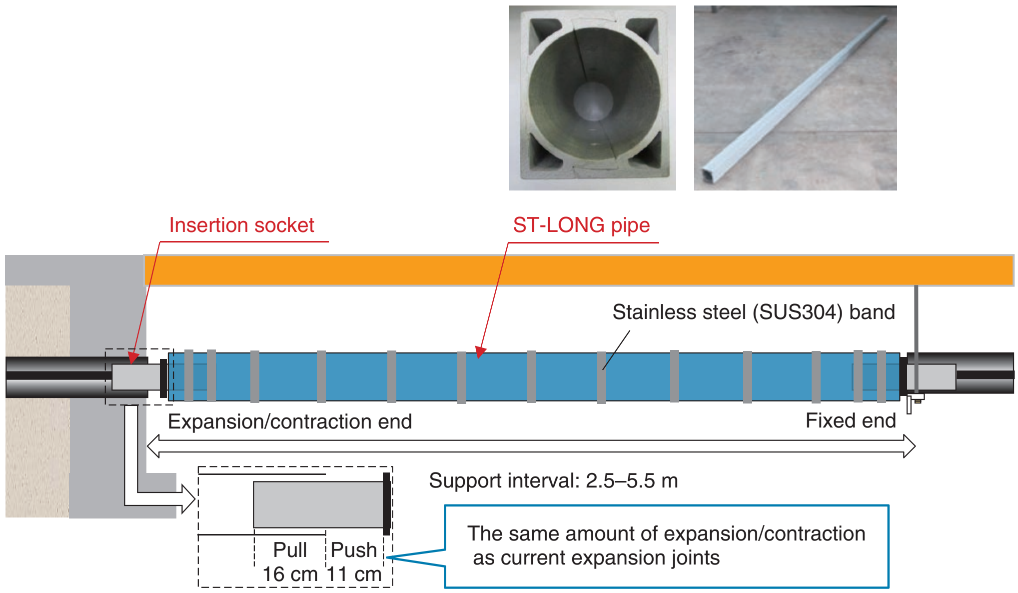


Fig. 7. New repair technology.

pipe to complete the replacement repair.

Because the old facilities to which replacement repair is applied have little capacity for expansion and contraction, there is concern about possible damage due to disconnection or buckling at the joints in an earthquake. We therefore designed the joints to have the same amount of expansion and contraction as current expansion joints, thus improving their resistance to earthquake damage in addition to enabling completion of the repair (**Fig. 7**).

The results of testing prototype ST-LONG pipe and insertion sockets for bending, strength, and vibration resonance with bridge structures confirmed that the developed components satisfy the permissible deflection at $L = 5.5$ m and that the strength and resistance to resonance effects are sufficient. We also evaluated repair workability with a model for conduit attached to a bridge. The results showed that the developed components provide good workability for multiple cable-conduits.

3.2 Expanding the applications of conduit cutting technology

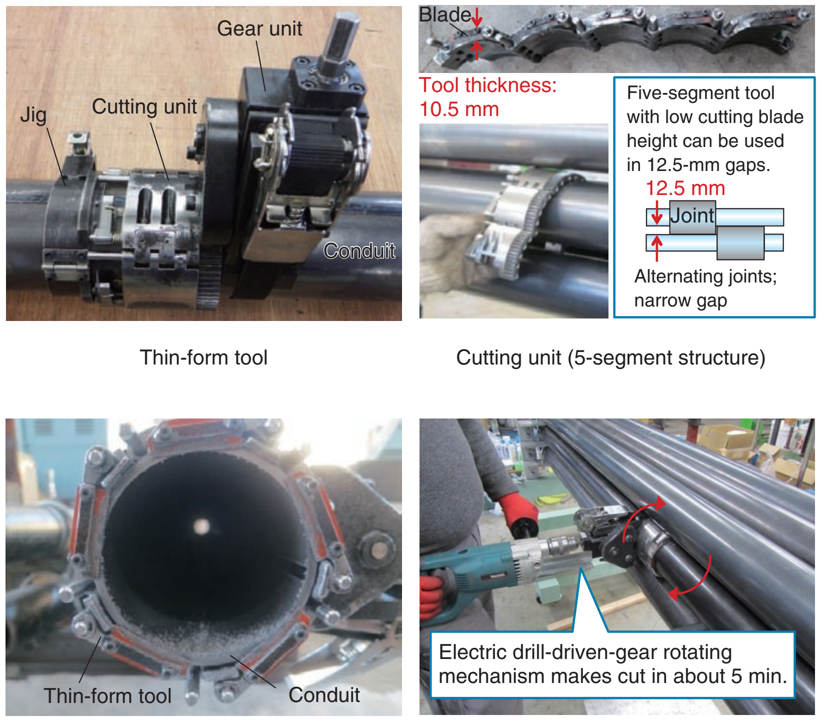
In places where the gap between conduits is less than 30 mm, the corroded part cannot be cut out and removed, so the current two-piece FRP repair pipe cannot be used for replacement repair in such cases. Conduit attached to bridges is installed densely because of the limited space, so narrow gaps between conduits are common. Replacement repair is performed using three main steps.

Step 1) Check whether or not conduit has cable.
Step 2) Cut and remove degraded conduit.
Step 3) Attach repair pipe.

The reason the corroded parts often cannot be cut and removed in step 2 is that current pipe cutting tools cannot be inserted into the narrow gap between the conduits. Also, the cutting is done manually using existing cutting tools, and this is inefficient for on-site work.

The technology we developed uses a low cutting blade height to achieve a low-profile pipe cutter (thin-form tool). The cutting unit is constructed of five segments and can easily be inserted into narrow gaps. As a result, the unit can be inserted into a gap as small as 12.5 mm, which is the narrowest gap assumed for places where conduit joints are installed in an alternating configuration. Furthermore, higher cutting efficiency is achieved by using a rotating cutter that has a gear mechanism driven by an electric drill. Whereas the current cutting tool requires about 15 minutes to make one cut in a conduit, this thin-form tool requires only about 5 minutes (**Fig. 8**).

Another problem with the current cutting method is that there is no protection for the cable inside the conduit. The reason for the lack of protection is the difficulty of inserting a protector into the conduit. To solve this problem, we developed a simple and sure



Thin-form tool — Cutting unit (5-segment structure) — Cross section — Pipe cutting

Fig. 8. Pipe-cutting tool (thin-form tool).

cable protection method to apply when the thin-form cutting tool is used. The method involves inserting a long, narrow protector through the hole used to check for cable in step 1 so that it wraps around the cable inside the conduit and keeps the cable away from the edge of the cutter blade. This prevents contact between the blade and the cable, ensuring protection of the cable during the cutting process. The protector is inserted by using a hammer in an operation that is easy to do even with thick and heavy cables. We evaluated a variety of materials for ease of insertion, strength, and cost, and selected 5.0-mm-thick polyethylene foam sheeting as a sample material to be used for the cable protector (**Fig. 9**). Commercial introduction of this protection technique for use together with the replacement repair technique described above is planned in FY2014.

3.3 Coating repair technology

Conduit that has superficial rusting where the corrosion is not severe is repaired by removing the rust and coating the affected area with polyurethane paint to prevent further corrosion. The purpose of repairing the conduit at the stage of light rusting is to halt the progression to the stage of corrosion degradation in which replacement is necessary. Currently, three coats of a polyurethane resin and epoxy resin rust-proofing agent are used. The coating is effective for 10 to 15 years, but this approach cannot keep up with the increasing number of deteriorating facilities.

We are therefore working on rust-proofing technology that remains effective for 40 years or more. The results of accelerated degradation tests performed in cooperation with the NTT Energy and Environment Systems Laboratories indicated that oil-based rust-proofing using wool wax is effective (**Fig. 10**). We found that rusting progressed after 2000 hours for currently used coatings (polyurethane resin), but there was no rusting after 6000 hours with an oil-based coating, which confirmed an improvement in durability by a factor of three or more.

The results of temperature and coating thickness tests showed that securing the target lifetime of 40 years requires a thickness of at least 0.5 mm of a cream-type oil-based rust-proofing agent. However, that type of rust-proofing agent does not harden, so it would be difficult to maintain the required thickness over the required period of time. We are therefore

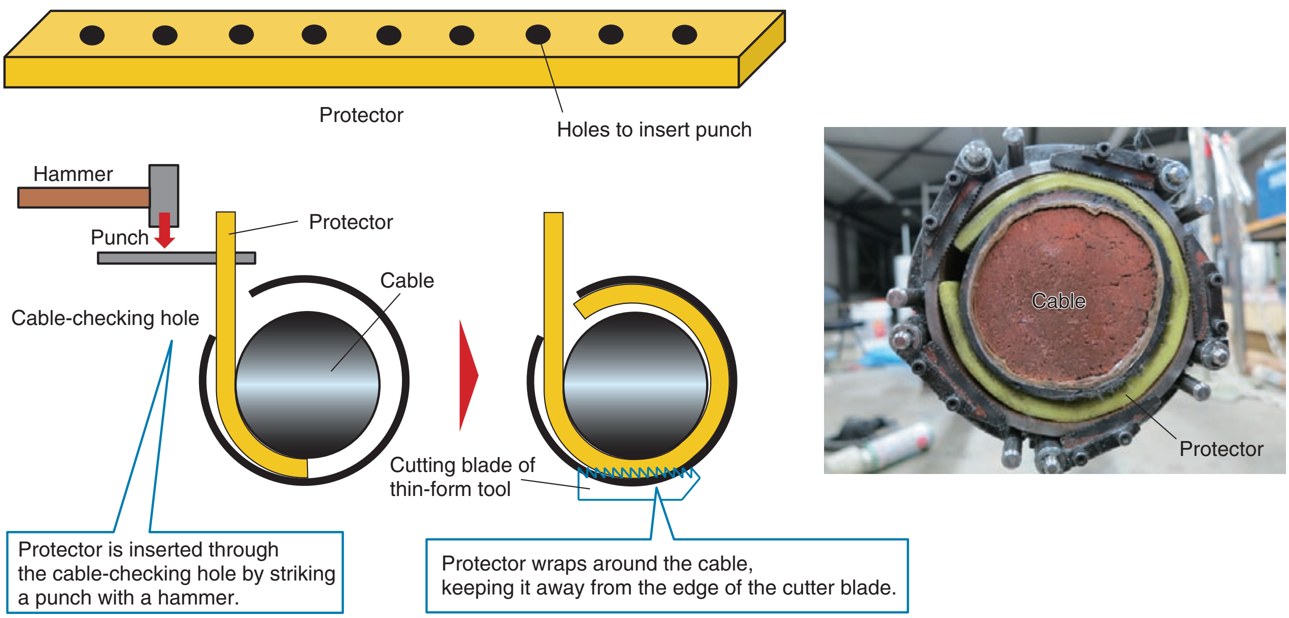


Fig. 9. Cable protection method.

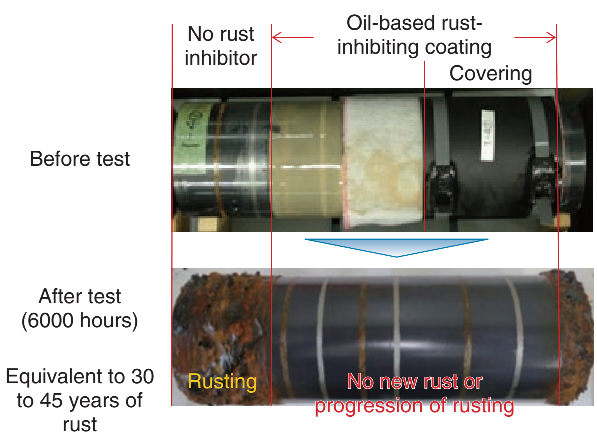


Fig. 10. Accelerated degradation test over 6000 hours.

investigating methods for using oil-based rust-proofing on conduit attached to bridges. Currently, the required coating thickness can be maintained by using cloth impregnated with the oil-based rust-proofing agent that is wrapped around the conduit. Therefore, we are continuing our efforts towards making this technique practical for use on bundled facilities and in places where the gap between conduits is small, aiming for commercial introduction in FY2015.

4. Future issues and prospects

Most of the NTT conduit facilities are buried beneath roads. Work on repairing or widening roads, sidewalk maintenance work, or work done on the underground facilities of other companies may disturb existing NTT conduit facilities or result in the need to relocate them. For spans that cross rivers, the facilities may also need to be relocated when NTT conduit attached to bridges and bridge facilities are rebuilt, reinforced against earthquakes, or painted.

We are also working on technology for reducing construction costs in order to deal with facility relocation. For cases in which new facilities are constructed after relocation, we will continue to investigate simple and economical facility designs that can flexibly cope with changes in capacity and transmission medium specifications, keeping future all-optical transmission in mind.

The increasing number of NTT conduit facilities that are degraded by aging and other factors remain a concern for the future. We will continue developing new technology to solve such problems and contribute to achieving higher network reliability.

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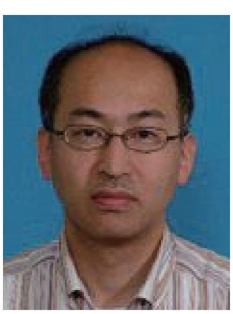

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Frequency-division-multiplexing Coherent OTDR for Realizing Effective Construction and Maintenance of Submarine Optical Cable Systems

Hiroyuki Iida, Kunihiro Toge, and Fumihiko Ito

Abstract

We have developed a novel coherent optical time domain reflectometry (C-OTDR) technique with the highest level of measurement sensitivity yet reported, thus enabling us to achieve the effective construction and maintenance of submarine optical cable systems. Our technique minimizes the operating time required during measurement. This article provides an overview and reports the features of our new technique, which we call frequency-division-multiplexing coherent OTDR (FDM-OTDR).

Keywords: C-OTDR, submarine cable, fiber measurement

1. Introduction

Submarine optical cable systems have been constructed and upgraded recently by employing novel transmission techniques such as digital coherent optical transmission in order to meet the demand for rapidly growing data traffic over optical trunk networks. Submarine optical cable systems are classified into two categories. One consists of *repeatered* systems for long-haul applications, which transmit signals over several thousand kilometers by using optical amplifiers (erbium doped fiber amplifiers (EDFAs)) and power feeding through submarine cables. The other consists of *repeaterless* systems for short-distance applications of up to several hundred kilometers. The fiber conditions in long-distance submarine optical cables need to be evaluated at various times including during an acceptance inspection and shipping of the cables, in a final inspection after laying the cables, and when identifying fiber faults during operation. Coherent optical time domain reflectometry (C-OTDR) [1] is normally used in such evaluations. C-OTDR is a mature technique with superior sensitivity and good characteristics for eliminating amplified spontaneous emission noise from optical amplifiers by employing coherent detection.

2. Problem with conventional C-OTDR

Submarine cable systems typically have long repeater spans for repeated systems, or a long transmission length in repeaterless systems, thanks to optical amplifiers with high total output power and low-loss optical fibers with large effective areas. C-OTDR is sensitive up to the shot noise limit of the receiver. However, one problem is that the dynamic range (DR) is sometimes insufficient when we evaluate the entire length of such submarine optical cable systems (**Fig. 1**). With C-OTDR measurement, a lot of time is needed to conduct a large number of iterations for averaging in order to obtain a good signal-to-noise ratio (SNR) in OTDR traces. Therefore, it is important to extend the DR in C-OTDR in order to minimize the operating time needed for cable inspection.

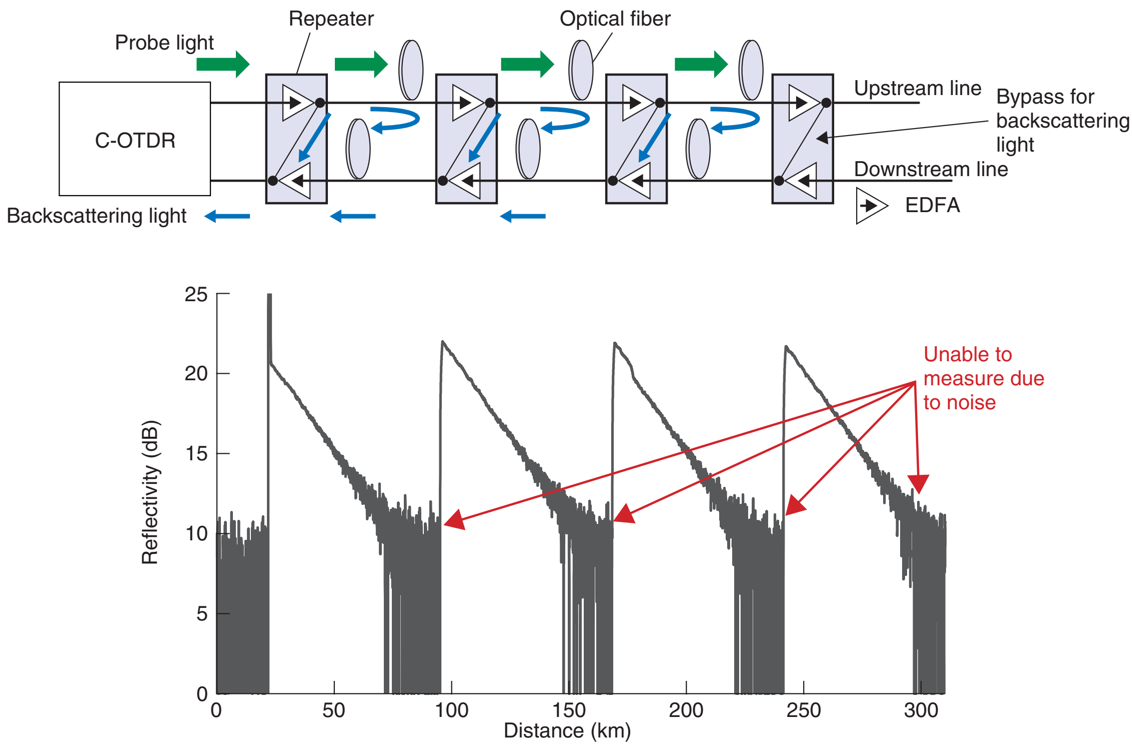

Fig. 1. Configuration of submarine optical cable system and overview of measurement of submarine optical cable using C-OTDR.

3. DR enhancement method for C-OTDR

The easiest way to extend the DR is to increase the peak power of the probe pulse from the C-OTDR. However, this does not apply to repeatered systems because the output power from the repeaters is restricted by the automatic level control function of the repeater itself. The frequency-division-multiplexing coherent OTDR (FDM-OTDR) technique we developed employs multi-frequency-coded probe pulses instead of the single-frequency pulse used in conventional C-OTDR [2]. The basic concept of our FDM-OTDR is shown in **Fig. 2**. A probe pulse train with N-multiple frequencies is launched into the fiber. Each frequency component is serially arranged in the time domain. These components are detected by a single photodetector, and they provide multiple OTDR traces measured at different frequencies by a fast Fourier transform (FFT). As a result, we can simultaneously obtain multiple OTDR traces measured at different frequencies. This means that OTDR traces with an SNR improved by $\sqrt{N}$ can be obtained within a single iteration of the measurement. In other words, an OTDR trace with the same SNR can be obtained during an N^{th} part of the measurement time by using FDM-OTDR. This concept was proposed by NTT several years ago [3]. However, it required a modulator in which the probe frequency could be controlled precisely and rapidly, as well as many electronic devices at the receiver for demultiplexing the signal, which has prevented the realization of a practical system for commercial use.

4. FDM-OTDR

An overview of the FDM-OTDR configuration we developed is shown in **Fig. 3**. The probe frequency of a continuous wave (CW) from one narrow-linewidth laser is controlled by an external modulator. On the receiver side, Rayleigh backscattering light with multiple frequencies is detected by a single coherent receiver and digitized with an analog/digital (A/D) converter. With FDM-OTDR, a digitized signal is demultiplexed by digital signal processing, which indicates that many electronic devices are not required. Therefore, FDM-OTDR is comparable to conventional C-OTDR in terms of size and cost. The details of the FDM-OTDR scheme are as follows.

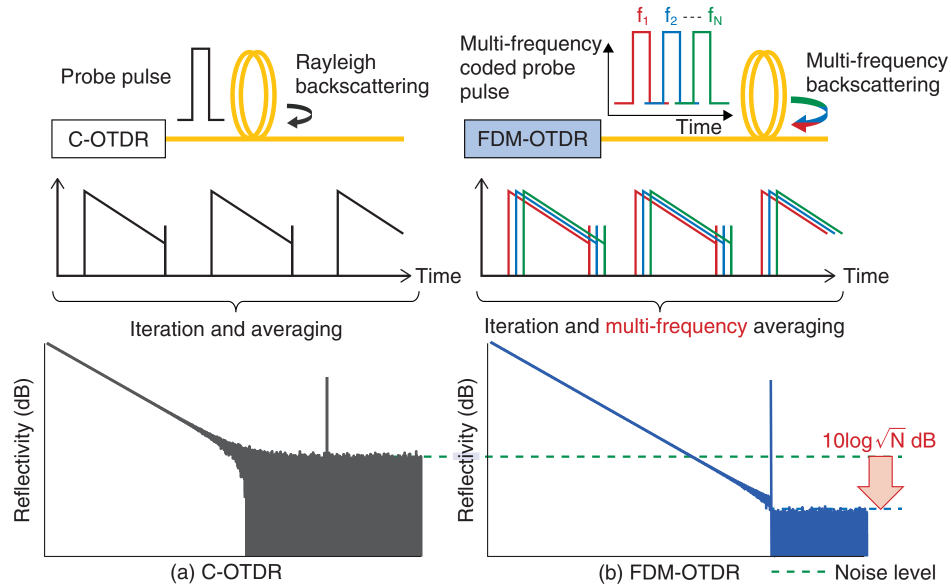

Fig. 2. Principle of FDM-OTDR.

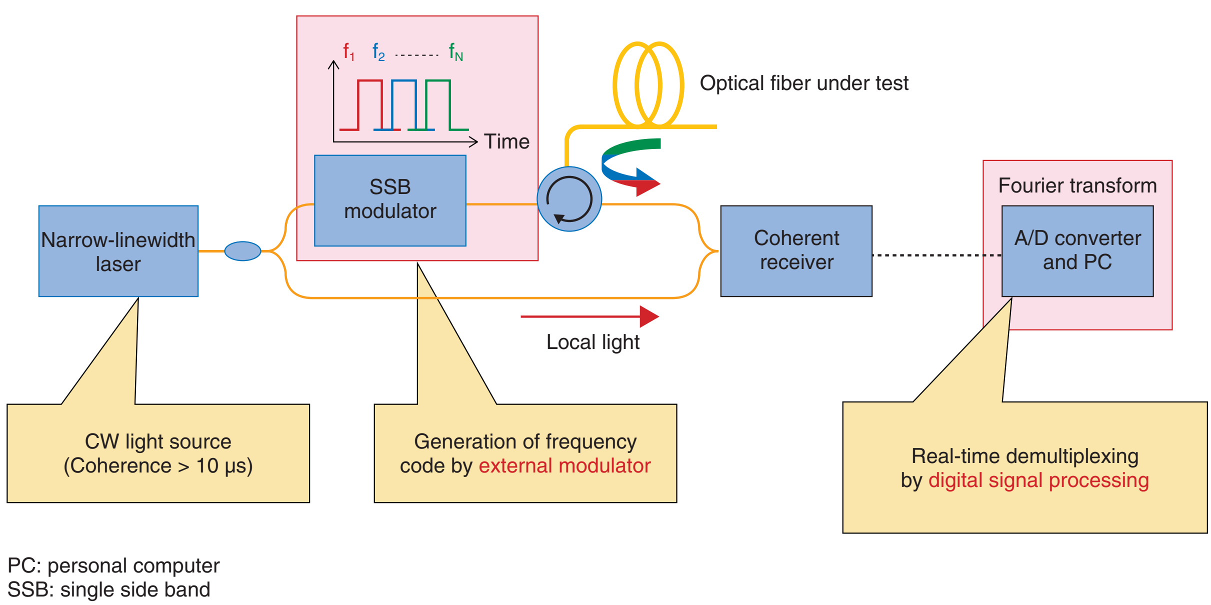

Fig. 3. Configuration of FDM-OTDR.

4.1 Frequency-coding of probe pulse

The frequency coding of a probe pulse on the transmitted side is shown in **Fig. 4**. It is performed with kHz-order accuracy by using an optical single side-band (SSB) modulator. The optical SSB modulator is controlled by using bias adjustment to modulate only the +1st order (or −1st order) component, and to suppress the carrier frequency component (CW from narrow linewidth laser) and higher order side-band components. The probe frequency is changed with a duration corresponding to the spatial resolution (namely, the pulse width in conventional C-OTDR). The number of multiplexed frequencies is limited by the receiver bandwidth. The frequency interval of the

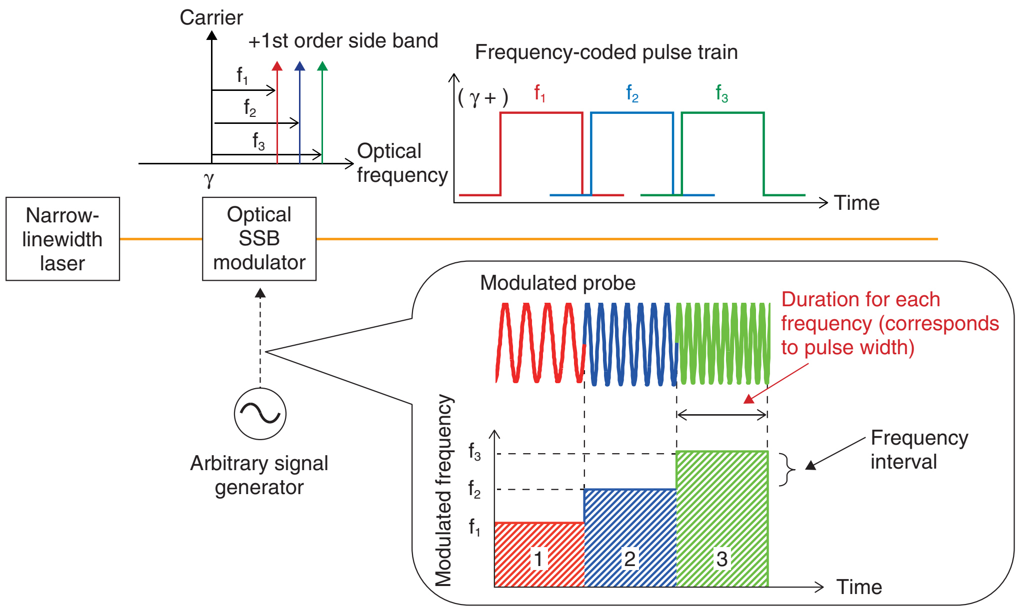

Fig. 4. Generation of frequency-coded pulse train in FDM-OTDR.

multiplexing is optimally designed in the receiver bandwidth to suppress crosstalk between frequency channels.

4.2 Frequency demultiplexing by digital signal processing

Rayleigh backscattering with multiple frequencies is detected and then digitized when a frequency-coded probe pulse is launched into an optical fiber under test (FUT). The digitized backscattered signals can be separated into each frequency component with an FFT. This signal processing is performed in real time during the round-trip time of the frequency coded probe pulse in the FUT, and it then provides the average OTDR trace from N OTDR traces. Consequently, FDM-OTDR requires significantly fewer iterations because the SNR in an OTDR trace with one iteration can be improved by $\sqrt{N}$.

4.3 Design of inter-channel crosstalk

The design of the inter-channel crosstalk in FDM-OTDR is very important because it appears as a distortion in an OTDR trace. Schematic illustrations of the distortion in an OTDR trace caused by inter-channel crosstalk are shown in **Fig. 5**. When we measure submarine cable systems, the reflectivity is precipitously changed with twice the gain (in dB) of the repeater. If the effect of inter-channel crosstalk greatly exceeds this reflectivity change, the shape of the OTDR trace in front of the repeater broadens as shown in the figure. This broadening in the OTDR trace can be considered degradation of the fundamental performance of OTDR measurement with respect to spatial resolution. Therefore, suppression of inter-channel crosstalk is an essential issue in FDM-OTDR. With our developed FDM-OTDR method, we employed an appropriate digital filtering technique to suppress the side lobes of the detected signals during processing. We also realized the optimal design of the frequency intervals to achieve the allowable inter-channel crosstalk and thus maintain a sufficient level of spatial resolution.

5. Characteristics in FDM-OTDR

Here, we introduce an example of the measurement results we obtained using the FDM-OTDR technique with 40-frequency-multiplexing that we developed.

The results of OTDR traces obtained for conventional C-OTDR and FDM-OTDR are compared in **Fig. 6**. The measurement conditions are the same in terms of iteration number (2^{13}) and spatial resolution (1 km). It can be seen from the figure that the round-trip DR of FDM-OTDR improved by about 7.8 dB, which agrees well with the theoretical improvement of about 8 dB ($\approx$ 10log $\sqrt{N}$). This means that the same SNR performance can be obtained in about 1/40 the measurement time by using FDM-OTDR.

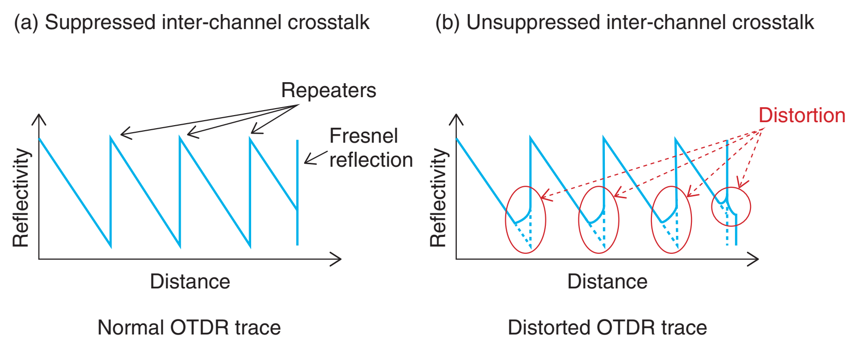

Fig. 5. Effect of inter-channel crosstalk on OTDR trace.

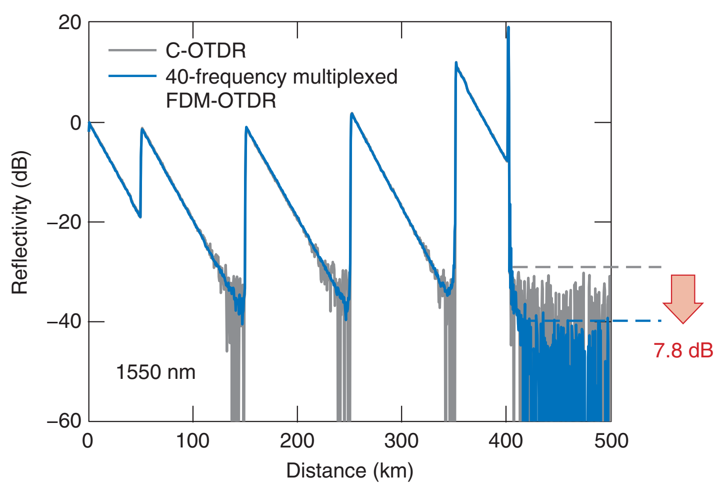

Fig. 6. Sample measurement result by FDM-OTDR.

An OTDR trace obtained in front of the last repeater is plotted in **Fig. 7(a)**, in which a huge change in the reflectivity is observed. Although we can see a marginal effect of inter-channel crosstalk when we compare conventional C-OTDR and FDM-OTDR traces, the inter-channel crosstalk is suppressed by more than 36 dB. In the Fresnel reflection in the trace obtained with FDM-OTDR at the far end of the FUT (**Fig. 7(b)**), it can be seen that the inter-channel crosstalk does not degrade the spatial resolution, and that we obtained the designed performance with 1 km for 3-dB spatial resolution.

As described above, our FDM-OTDR technique enables us to minimize the measurement time without any degradation in spatial resolution.

6. Future perspectives

This article introduced FDM-OTDR with 40-frequency multiplexing, which can minimize the operating time required during the construction and maintenance of submarine cable systems. The software-based processing in the FDM-OTDR benefited from recent increases in the capacity of computer processors. We have also reported 200-frequency-multiplexed FDM-OTDR [4]. The FDM-OTDR performance, namely, the number of multiplexed frequencies, strongly depends on the performance of the hardware, for example, the A/D converter and computer processor. Noteworthy recent progress has been made on an A/D converter with a broad bandwidth and a field programmable gate array for high-speed FFT implementation. The FDM-OTDR can potentially evolve further by employing such progress. We

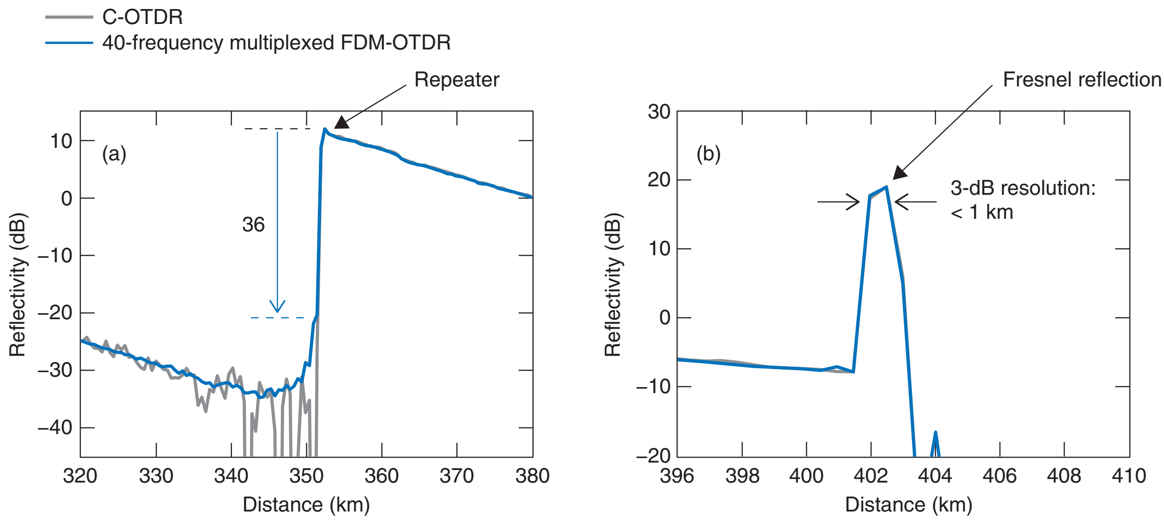

Fig. 7. Enlarged view of OTDR traces (a) in front of repeater, (b) at Fresnel reflection.

expect FDM-OTDR to be deployed for practical applications in the near future since a short measurement time is advantageous with respect to reducing the construction and operating costs of submarine networks.

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Development of Long-span Aerial Cable Installation Technique (Long Hanger Method)

Katsuhisa Kawaguchi, Ryosuke Yasui, Ryoichi Kaneko, Kunihiro Shimokubo, Kazutoshi Takamizawa, and Yuji Aoyagi

Abstract

We have developed a technique called the long hanger method for installing a long span aerial cable across, for example, a valley or river without using conventional methods that require special skills or installation tools. Our new method enables us to easily overlay or replace cables.

Keywords: long-span aerial cable installation, rural area, overlay/replace cables

1. Introduction

When optical services were being developed for NTT EAST and NTT WEST, optical equipment was deployed throughout the country. Facilities were already adequate in most urban areas, so the development of rural areas was planned for the future. The environment in rural areas is different from that in urban areas in terms of the distances between NTT buildings and customer premises, as well as customer density. Therefore, we require components and installation methods that are suitable for rural environments. An example is the aerial cable installation technique used for 200- and 250-m long-span sections over valleys or rivers. Conventionally, we use a catenary method or a lashing method, but they give rise to the following two problems.

(1) Installation

The catenary method requires a special skill (the ability to do aerial work) for construction to be completed safely (**Fig. 1**). The lashing method requires a special tool (lashing machine). The widespread application of this tool ended decades ago, and it is now only required for long-span sections (**Fig. 2**). Today, few engineers have the skill required to do aerial work, and lashing machines that meet NTT specifications are no longer produced. Therefore, it will be difficult to continue using these methods in the future. In addition, the catenary method was used for cable restoration work after the Great East Japan Earthquake, and it took a long time to secure the required personnel and to conduct the preparatory work for building the facilities. Therefore, new technology is needed that can reduce the cable restoration time.

(2) Components

With these conventional methods, overlaying or replacing a cable takes an equivalent amount of time as that originally needed to install the same components because of the difficulty in installing an additional cable.

We have developed the long hanger method as a solution to these two problems.

2. New development concept

We first explain the problems regarding the catenary and lashing methods. The components used with the catenary method consist of two messenger wires (a main messenger wire and a sub-messenger wire), a

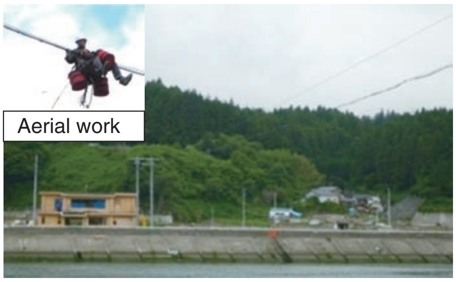

Fig. 1. Catenary method.

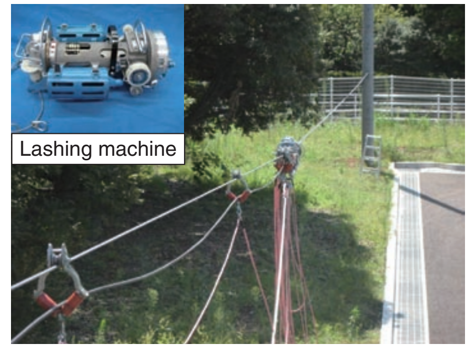

Fig. 2. Lashing method.

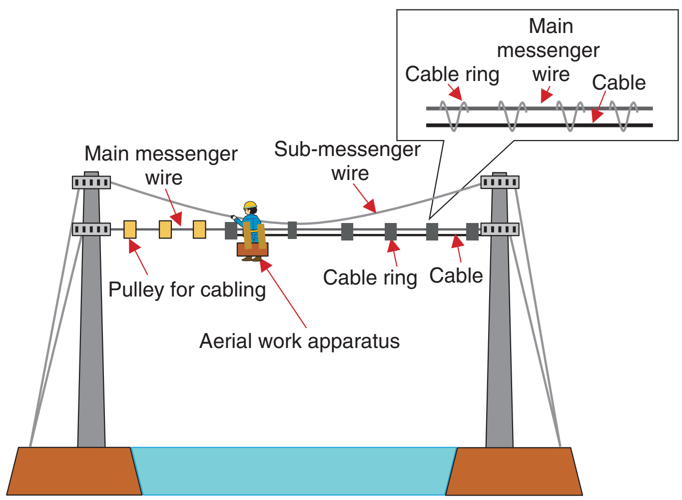

Fig. 3. Equipment and installation using catenary method.

cable, and cable rings (**Fig. 3**). It is necessary to do aerial work (i.e., to work in mid-air) using a specially designed apparatus when fixing the main messenger wire to a sub-messenger wire during the temporary installation of a cable, and when attaching cable rings. This is also the case when we install an additional cable, where we must remove and reattach cable rings individually. This means that it takes a long time to install an additional cable. Replacing the cable takes even more time because we have to remove the cable in addition to carrying out the above process.

The lashing method was developed to eliminate the need for aerial work. The lashing method employs a messenger wire, a cable, and a lashing wire (**Fig. 4**). In the installation, we first place a lashing wire in a lashing machine and then fix a messenger wire and a cable in place with the lashing wire. The lashing machine can be used over a long-span section, so aerial work is not required. However, lashing machines that meet our specifications are no longer being produced, and therefore, we cannot continue to use this method. In addition, if we overlay a cable using the lashing method, it will be necessary to carry out the installation of a messenger wire, a cable, and a lashing wire as if it were a new installation, which would take a long time. Replacing the cable takes even more time because we have to remove the existing cable in addition to completing the above installation process. Our aim with the long hanger method was to employ the binding hanger used for conventional aerial sections and create a space in which we can overlay and remove cables freely without the need for aerial work or a special tool. We developed a

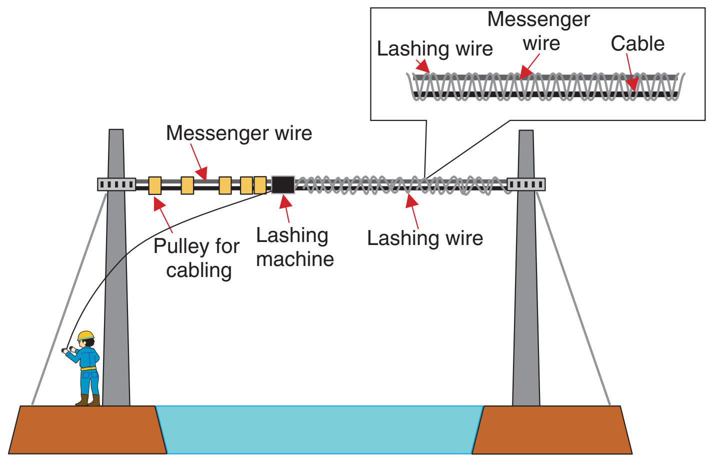

Fig. 4. Equipment and installation using lashing method.

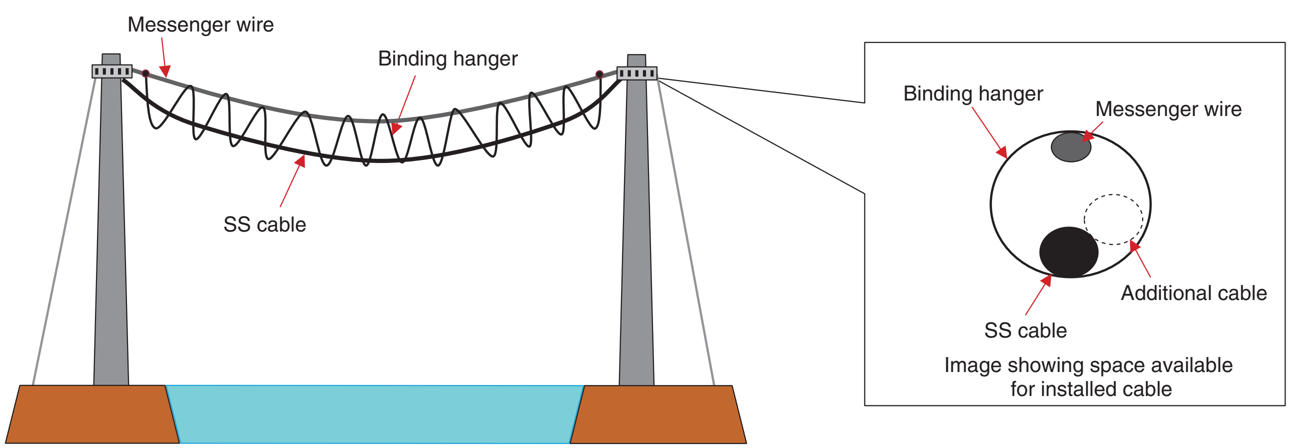

Fig. 5. Equipment used in long hanger method.

safe installation technique for 250-m spans and highly reliable equipment that can be used in various environmental conditions such as strong winds.

3. Required components

The components required for the long hanger method include a messenger wire, a binding hanger, and cables (**Fig. 5**). The role of the messenger wire is to support the load of all components as well as the load applied by wind pressure. The binding hanger creates a space in which we can freely overlay or remove cables. From several types of binding hangers, a cosine curve hanger (CCH) is used in this method because it can be coiled up compactly even if it is long. A stopper is used to fix the CCH to the messenger wire, which further improves the reliability (**Fig. 6**). This stopper prevents the CCH from moving away from the messenger wire and prevents cables from falling out of the CCH because the internal space of the CCH is enclosed. A self-supporting (SS) cable is used to prevent fiber movement and fiber strain.

4. Installation

In a standard aerial section, we first install a messenger wire and then a CCH by pushing the CCH out

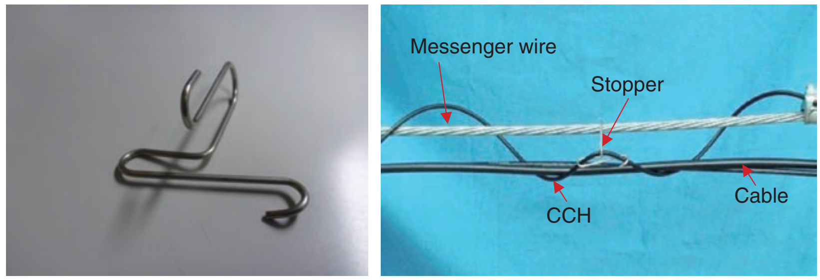

Fig. 6. Stopper installation.

along the messenger wire from a given pole. However, if we want to install a CCH in a log-span section, we cannot get it all the way over to the other pole because the friction against the messenger wire increases with a slack and steeply pitched messenger wire. Alternatively, when we pull a CCH from one side, it can be stretched as a result of the large tension. This reduces the internal space of the CCH and makes it impossible to overlay and replace cables.

With the long hanger method, we install a messenger wire and a CCH simultaneously. This approach reduces the tension on the CCH and makes it possible to get the CCH all the way over to the other side. The procedure is as follows:

(1) A light rope is first installed between the poles (the same process as in the conventional method).

(2) Two ropes are then installed between the poles by connecting them both to the first light rope and pulling it. (**Fig. 7(a)**).
Rope A: messenger wire
Rope B: SS cable
Wiring rings are used to lift rope B across a long span.

(3) A messenger wire and a CCH are installed by pulling rope A and adding stoppers (**Fig. 7(b)**). Rope B is fixed to the poles, and it prevents the messenger wire and CCH from falling down between the poles of the long span section. A conventional winch can be used for this process because rope B can reduce the tension needed to pull the messenger wire and the CCH.

(4) Tension is applied to the messenger wire, which is then fixed to the poles; a space has been included for freely overlaying and removing cables.

(5) An SS cable is installed by connecting it to rope B and then pulling on rope B (**Fig. 7(c)**).

(6) The SS cable is fixed to the poles.

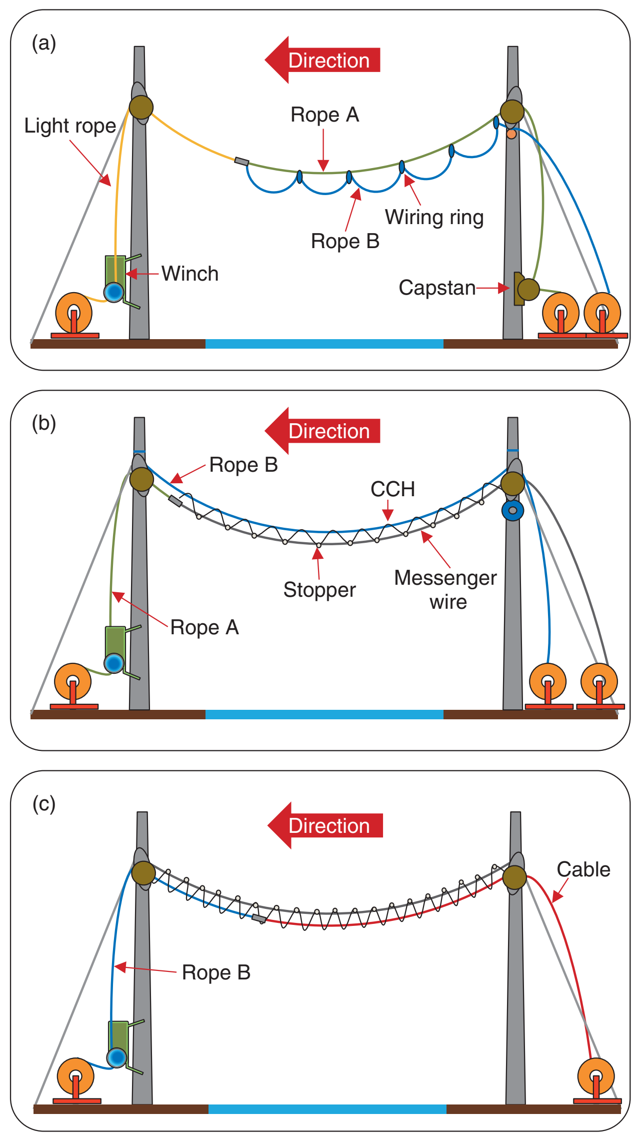

Fig. 7. Installation using long hanger method.

5. Overlaying/replacing a cable

In a conventional aerial section, when we overlay or replace a cable, we use a wiring method that involves pushing a shuttle that carries the wire from one side and passing it through the CCH. However, we cannot use this approach in a long-span section because the shuttle falls from the CCH as a result of the large amount of slack. Therefore, we adopt an approach where a wire is installed at the same time the cable is first installed. In this way, we can pass the CCH through without fail and eliminate the later wiring process.

6. Conclusion

The long hanger method is highly versatile because the tools it requires—namely, ropes, a winch, and so on—are in general easily available. In addition, we confirmed the high reliability of the components used in this method, which is important since they are exposed to extremely windy environments with large temperature fluctuations. This method is scheduled to be introduced in 2014 by NTT EAST and NTT WEST. We will assist each company with its introduction.

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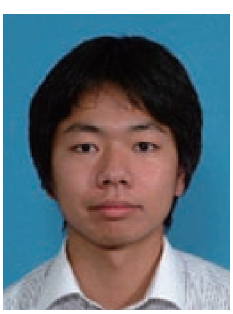

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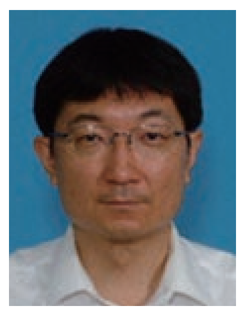

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IEC Standardization Trends Related to Energy Infrastructure

Keiichi Hirose

Abstract

The globalization of corporate activities and the expanding markets of emerging economies in recent years has made international standardization more important than ever. This article describes the standardization activities of the International Electrotechnical Commission concerning direct current power supply systems as part of international standardization efforts in the field of energy, which has been the focus of attention in recent years. The main trends in the field of smart grid communities are also introduced.

Keywords: IEC, energy infrastructure, DC power

1. Introduction

The energy shortages caused by the major earthquake disaster that occurred in eastern Japan in March of 2011 and the need to avert global warming and other environmental issues have led the NTT Group to focus more attention on the field of energy, in addition to the field of information and communication technology (ICT) that has been our traditional focus. NTT Facilities has been the most actively engaged in international standardization activities related to energy in combination with their on-going work in technological development, various kinds of field testing, and commercialization studies. This article introduces the main trends in international standardization in the field of energy based on the activities of the International Electrotechnical Commission (IEC) concerning the direct current (DC) power supply that the NTT Group has been recommending [1].

2. Background on the need for international standardization [2]

The importance of international standardization became clear with the introduction of the 1995 WTO/TBT (World Trade Organization/Technical Barriers to Trade) Agreement and the 1996 WTO Government Procurement Agreement, which oblige nations to use international standards as the basis for procurement standards. The advanced nations of Europe and North America have placed importance on conducting vigorous international standardization activities to strengthen their international competitiveness. Many countries have also been actively trying to use international standardization as a strategic tool with a view to cultivating emerging markets. Japan, too, has placed importance on ensuring that international standards are set as a component of a long-term strategy. In Japan's revitalization strategy, too, there is a need to take the lead in international standards in fields where Japan has strength, including smart grids and energy-efficient infrastructure.

3. IEC and its organizational structure [3]

IEC is an international organization that sets standards for electrical and electronic technology; it was established in 1906 and comprises member National Committees that represent individual countries. Japan is represented by the Japanese Industrial Standards Committee (JISC), which serves as an umbrella for about 300 associations and scientific societies within Japan that are engaged in drafting and studying international standards for various specialized fields. About 7000 IEC standards have been set, and expansion

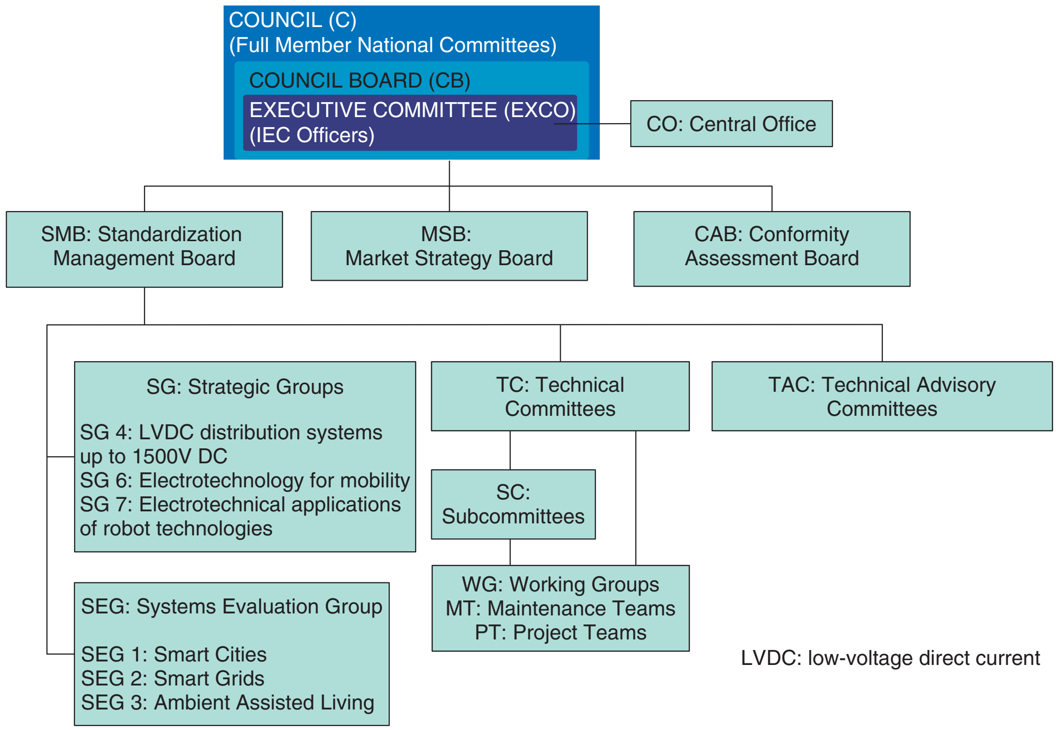


Fig. 1. Organization of the IEC.

of standards for electric vehicles, storage batteries, and smart grids, as well as for semiconductor devices, home electronics, and other fields that are deeply linked to energy infrastructure and equipment is expected in the future.

The organizational structure of the IEC is shown in **Fig. 1**. Within the IEC, there are over 100 Technical Committees (TCs) and Subcommittees (SCs) that cover all sub-fields of technology.

The IEC also includes Strategic Groups (SGs) that are set up for limited periods of time to put together proposals on the direction, issues, and recommendations concerning international standards. It has also been recognized that standardization based on entire systems is necessary, and therefore, the IEC has decided to set up Systems Committees (SyCs) for establishing standards for systems that span multiple TCs/SCs rather than simply the conventional TCs/SCs that deal only with individual products.

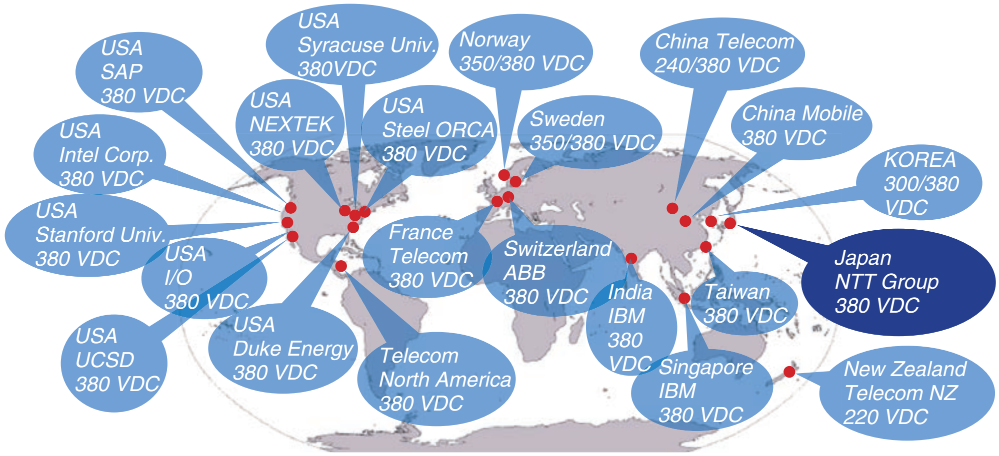
The Systems Evaluation Groups (SEGs) are set up prior to setting up SyCs. They conduct feasibility studies to investigate the future potential for creating international standards in particular fields. The results of these studies by SEGs serve as the basis for the future establishment of SyCs.

4. Activities concerning DC power sources

The NTT Group began seriously studying high-voltage DC power supply systems in 2000. With the acceleration of commercial introduction within the NTT Group in 2014, we have made progress in long-term technological development. Those activities are now expanding in various countries around the world as well as in Japan (**Fig. 2**), and there is a need for international standards for worldwide compatibility. Below, we introduce the standardization activities concerning DC power supplies within the IEC.

4.1 SG 4 activities

The DC power supply systems that have been attracting attention in recent years have applications in many fields other than ICT, and development as energy systems for commercial buildings, future residential buildings, distributed power systems, and charging of electric vehicle batteries is expected. Building on such work, the Swedish National Committee (SENC) proposed that the IEC set up an SG to study the standardization of DC distribution systems up to 1500 V, and the approved SG 4 (LVDC (low-voltage DC) distribution systems up to 1500 V DC in



UCSD: University of California, San Diego
VDC: volts direct current

Fig. 2. Introduction and testing of high-voltage DC power systems.

relation to energy efficiency) started activities in 2009, which include considering the IEC standards required for DC power supplies, creating a road map, and analyzing market trends.

4.2 TC and SC activity

In addition to SG 4, various other activities for actual standardization have begun within the IEC. Examples showing the scope and present situation of international standardization studies related to DC distribution as of May 2014 are shown in **Fig. 3**.

Because of the need for standards concerning uninterruptable power systems, rectifiers, and power converters, SC 22E and SC 22H respectively began activities in 2013 and 2014. If those activities result in international standards, we can expect future promotion of the universal use of DC power supplies and expansion of the practical range and markets for them by JISC as well as by the IEC.

SC 23E is working on DC breakers for wiring and short-circuit breakers. Outside the field of ICT, the introduction of mega-solar facilities and photovoltaic (PV) panels for ordinary homes and buildings is expanding rapidly. Because PV panels output direct current, their characteristics when a short circuit occurs differ from those of alternating current (AC) power sources. For that reason, specifications are needed that are optimized for DC and are different from the specifications for circuit breakers for AC or for both AC and DC. An expected result of the SC 23E activities is the issuing of circuit breaker specifications that further improve the safety of DC power sources.

TC 23/WG 8 activities for DC socket and plug standardization began in 2009. These efforts include the 400 volt DC (VDC) socket and plug specifications developed by both NTT Facilities and Fujitsu Components, which served as the basis for draft international standards. Currently, the AC systems being used in various countries and areas lack uniformity and vary in frequency, voltage, and socket and plug shape. DC power sources are expected to be introduced in greater numbers in the future, and thus, international standardization to ensure uniformity of shape and regulation will benefit many of the involved parties.

Furthermore, grounding and protective systems for regulating safety and preventing electric shocks, as well as equipment and instrumentation, are important for DC systems just as they are for conventional AC systems. In the IEC, TC 64 is charged with setting and managing regulations for electrical installations and protection against electric shocks. In TC 64, too, discussions on DC power sources, including grounding and protective systems, are in progress.

With the recognition that the scope of future studies includes DC power meters, load equipment switches, charging systems for electric vehicles, DC microgrids (small power grid systems capable of functioning autonomously), and DC power distribution in residential or commercial buildings, regions, etc., we expect specific standardization discussions in those

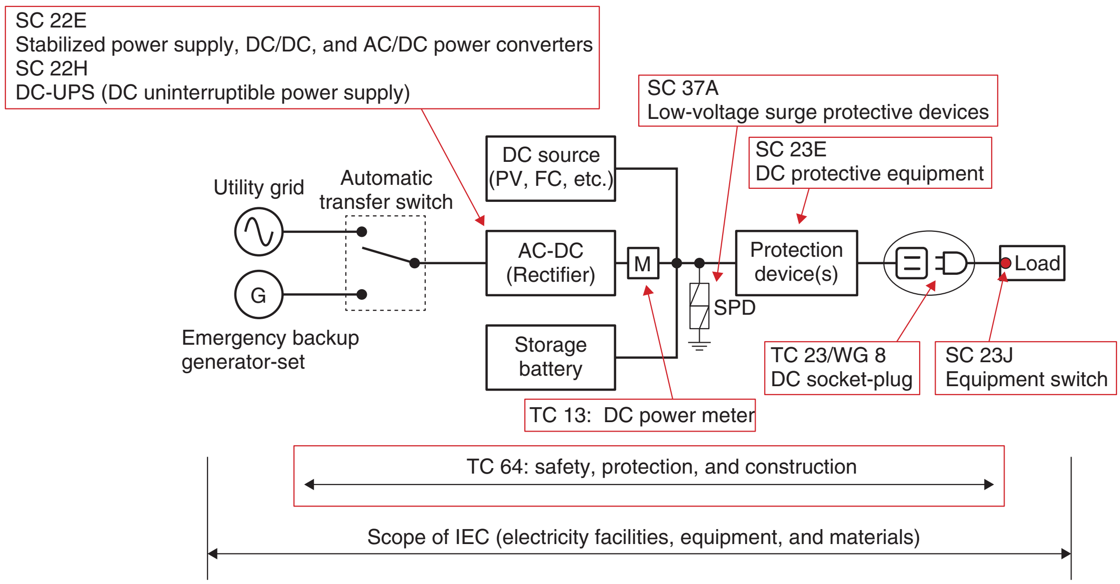


Fig. 3. Current scope of IEC studies on DC power supplies.

areas to proceed in addition to the activities depicted in Fig. 3.

5. Efforts in the field of (smart) energy infrastructure

IEC work on international standardization of smart grids is accelerating. IEC communities involved with smart grids are listed in **Fig. 4**. Japan, too, has taken an interest in this field, and various activities are underway. IEC activities concerning smart grids and smart cities are described below.

5.1 TC 120 Electrical Energy Storage Systems

In October 2012, the IEC approved the formation of a new Technical Committee for storage batteries and other EES (electrical energy storage) systems (TC 120) that connect to smart grids. This new committee was proposed by Japan, and Japan is serving as the secretary, while Germany is the convener. The results of experiments being conducted in various countries that are relevant to businesses involved in constructing environmentally friendly smart communities are expected to serve as the basis for future international standards.

5.2 SEG 1 Smart Cities

Japan, Germany, and China have made joint proposals involving smart cities, and those proposals have been approved. SEG 1 Smart Cities has been set up, and studies on the feasibility of international standards have begun within the IEC. The role of infrastructure in city functions is important in terms of business continuity planning, and discussions on the technical requirements that will become necessary from the viewpoint of future international standardization are planned.

SEG 1 is planning activities that include compiling descriptions of the activities within IEC and ISO (International Organization for Standardization), establishing the standardization scope and categories, evaluating marketability, defining terms, conducting case studies, creating a standardization road map, and collecting relevant information.

5.3 SEG 2 Smart Grid (formerly SG 3)

SG 3, which has been discussing smart grids, has been reorganized as SEG 2 in order to begin establishing international standards. As mentioned in section 3, the reorganization is part of the progression from SG to SEG to SyC. Exchanges of opinions and vigorous discussions in this field are expected, with the goal of establishing future IEC standards.

In SEG 2, further discussions in the field of smart grids, including smart energy, are anticipated in order to prepare for the future transition to an SyC. In addition, the SEG is expected to provide coordination and guidance on system level standards in the area of smart energy, including heating/cooling and the use of gas and electricity.

International standardization activities concerning smart cities have been intensifying.
For example, new TCs related to renewable energy and the smart grid have been established.

Year established	IEC community	Secretary	Convener (Chair)
2007	TC 114: Marine energy	UK	USA
2008	TC 115: High voltage direct current (HVDC) transmission for DC voltages above 100 kV	China	Germany
2011	TC 117: Solar thermal electric plants	Spain	Israel
2012	PC 118: Smart grid user interface	China	France
2012	TC 120: Electrical energy storage (EES) Systems	Japan	Germany
2013	SEG 1: Smart cities	Central Office	Japan
2013	SEG 2: Smart grid	Central Office	France

Smart energy has become the most important field in international standardization efforts.

Source: Recreated by the author based on the document "Strengthening International Standardization Policy for 2014," Ministry of Economy, Trade, and Industry of Japan, October 2013 (in Japanese).

PC: Project Committee

Fig. 4. Efforts to strengthen (smart) energy infrastructure.

Cooperation with SEG 1, future SEGs, related IEC internal organizations, and with ISO and ITU (International Telecommunication Union) is also anticipated.

6. Future developments

In the IEC, international standardization concerning energy infrastructure in relation to smart grids is actively underway, and the Japanese government is also placing importance on such activities. The IEC is also working on standardization of the DC power supply as a smart grid subsystem, and standardization work is proceeding in coordination with the activities of ITU-T (ITU-Telecommunication Standardization Sector) and ETSI (European Telecommunications Standards Institute), etc.

Increasing the efficiency and convenience of energy systems will be beneficial to many parties. The cooperation of international standards organizations, scientific associations, and the members of the NTT Group is more important than ever before, and it is necessary to continue to promote international standardization activities in this field well into the future.

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He is a member of The Institute of Electrical and Electronics Engineers (IEEE), the Institute of Electrical Engineers of Japan (IEEJ), the Institute of Electrical Installation Engineers of Japan (IEIEJ), and the Institute of Electronics, Information and Communication Engineers (IEICE). He is also very active in many standards bodies in areas associated with power systems. He is a member of the IEC SMB (Strategic Management Board) SG 4, a member of the Green Grid Power sub-working group, chair of the IEC SC 22E Japanese NC, and a recent past secretary of the IEEJ Investigating R&D Committee into DC power distribution.

He was awarded the IEEE PELS (Power Electronics Society) INTELEC 3rd best paper award in 2009, the outstanding paper prize from IEEJ in 2010, the best paper award of IEIEJ in 2013, and the Scientific Award of the Japan Society of Energy and Resources in 2013. He was also awarded the Hoshino Award of IEIEJ in 2014.

NTT Com Security

Tetsuo Someya, Chief Business Development Officer and Chief Governance Officer

Abstract

NTT Com Security, the successor to security specialists Integralis (Germany) and Secode (Sweden), launched its comprehensive risk management service called WideAngle in June 2013. This article introduces the work of NTT Com Security while describing the information security environment surrounding today's corporations.

1. Introduction

NTT Com Security provides information security services. Its main office is located in Germany, and the company is listed on the German stock exchange. Its parent companies are Integralis, a German company founded in 1988, and Secode, a Swedish company founded in 1986, both of which were acquired by NTT Communications—the former in 2009 and the latter in 2010. The two companies merged in 2011 and changed their name to NTT Com Security in October 2013. NTT Com Security has just started afresh as a company at the core of the security services business in the NTT Communications Group (**Fig. 1**).

NTT Com Security has been a leading company in the security field for over 25 years since its initial founding. It has been expanding its business with a focus on Europe and the United States and is now developing its business in the Asia Pacific region (**Fig. 2**).

NTT Com Security employs about 870 people worldwide, of which more than 500 are skilled personnel such as consultants specializing in security or security analysts prominent in the field. It consists of a main office and branch offices in 15 countries around the world. More than 200 of these employees are working as security engineers or risk analysts at Global Risk Operations Centers in seven countries. Their job is to perform security monitoring for NTT Com Security customers 24 hours a day, 365 days a year and to keep track of global security trends.

2. Current state of security market

A common theme today is that security is something that cannot be ignored in an environment of advanced communications technologies, BYOD (Bring Your Own Device) policies, and big data applications. Hacking of information related to financial, government, and military institutions, as well as hacking of confidential information to conduct electronic commercial transactions (e-commerce), and hacking simply for financial gain, occur on a daily basis in an increasingly organized and sophisticated manner. Another side of technological progress is the numerous examples of commonly used services that are being exposed to security threats, which results in a less reliable social infrastructure. Specifically, it has become clear that serious vulnerabilities such as Heartbleed, which was uncovered in the OpenSSL cryptographic library, and those in Apache Struts 2, a widely used open-source framework for creating web applications, have exposed many transactions on the web to the risk of information leaks, resulting, for example, in the temporary closure of a website used

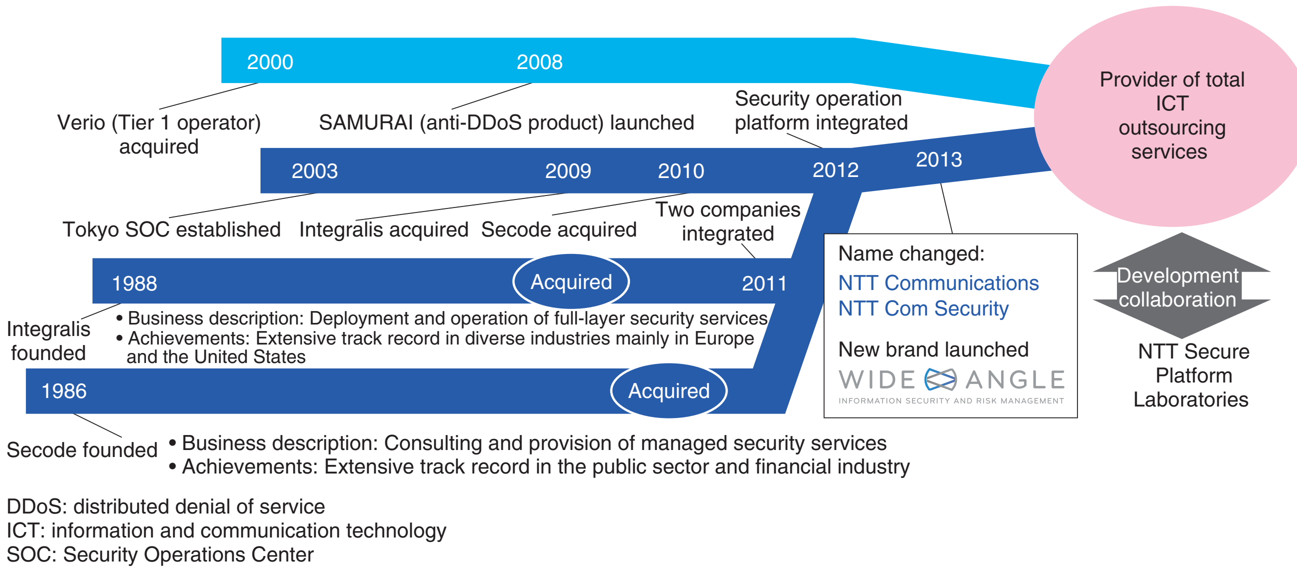

Fig. 1. History of NTT Com Security.

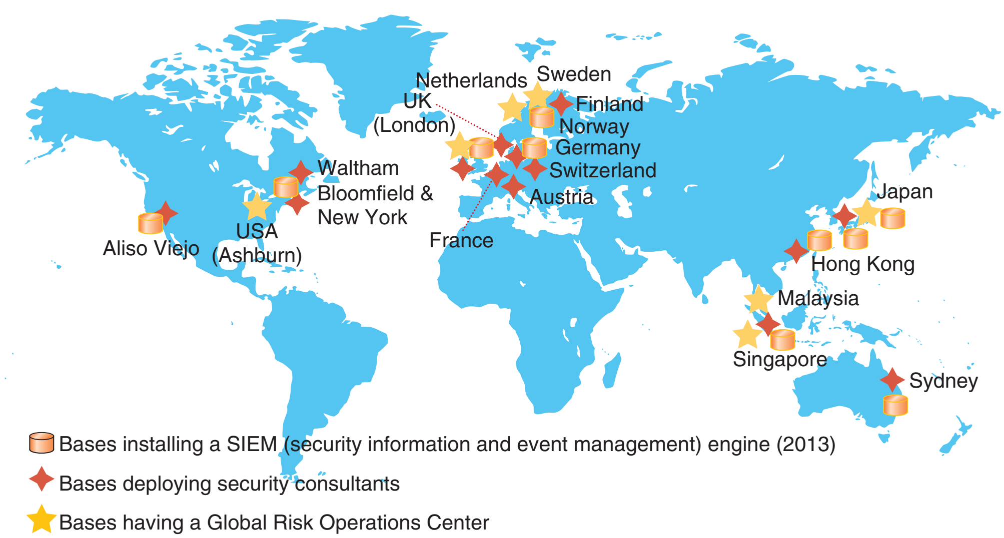

Fig. 2. Global expansion of NTT Com Security business.

for filing income tax returns.

In March 2014, the NTT Group published the Global Threat Intelligence Report (GTIR) based on recent attacks and a massive security-monitoring log (**Fig. 3**). This report was prepared and released by NTT Innovation Institute, Inc. (NTT I^3) in cooperation with NTT Group security companies (Solutionary, NTT Com Security, Dimension Data, and NTT DATA) and NTT laboratories. Through an analysis of more than 3 billion recent security attacks and security log data covering several trillion cases obtained through monitoring at 16 Security Operations Centers (SOCs) worldwide, this report provides useful information on what information assets attackers are aiming for and what methods they are using, and on how an organization can protect itself.

According to this report, 34% of all known attacks are related to client botnet activity and 15% to anomalous behavior, i.e., unnatural or abnormal communications (**Fig. 4**). This means that, for about half of all attacks, users' internal terminals or users themselves are either knowingly or unknowingly complicit in the attacks. An enterprise must take countermeasures against the risk of becoming a victim and of simultaneously becoming a perpetrator. Furthermore, it goes without saying that individual employees can expose the enterprise they work for to major lawsuits or compensation claims by causing internal or external damage.

There are cases in which a system manager's terminal within a corporate network becomes infected with malware that then spreads throughout the network unbeknown to that manager. It is clear from survey materials that most such cases result in large monetary losses. The GTIR states that the monetary damage per incident of this type is estimated to be about US$110,000.

Fig. 3. Global Threat Intelligence Report.

Malware is continuously evolving to evade system managers and diverse security measures. The same survey revealed that 54% of new malware gathered by honeypots set up by the NTT Group for research purposes could not be detected by existing anti-virus software and similarly that 71% of malware gathered in a sandbox environment could not be detected by up to 40 existing virus countermeasures.

New types of attacks that are mounted from either inside or outside a company directed at information assets appear daily, so it is impossible to protect oneself by simply introducing security devices and security software. It is important to have a security maintenance mechanism that can defend against both external and internal attacks and deal with new attack techniques on a continuous basis. Furthermore, when selecting a security service or vendor, it is important to consider whether the service or company can provide a mechanism not just for end-point security but also for detecting malware throughout the corporate network and cloud and whether that mechanism can uncover vulnerabilities and understand the nature of attacks. It must also be considered whether a security service or vendor can provide resources for keeping up with the latest security trends.

3. New service brand—WideAngle

The market focused on by NTT Com Security is mainly corporate information security management consisting of three business domains: (1) professional services, (2) sales and deployment of security devices, and (3) managed security services (MSS).

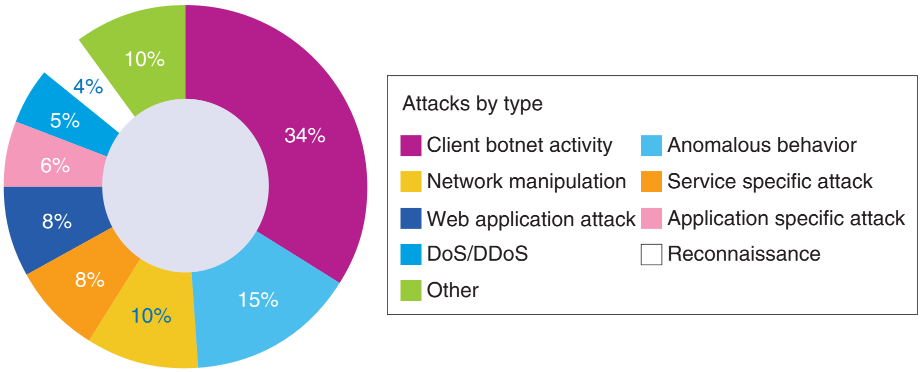

Fig. 4. Breakdown of security attacks.

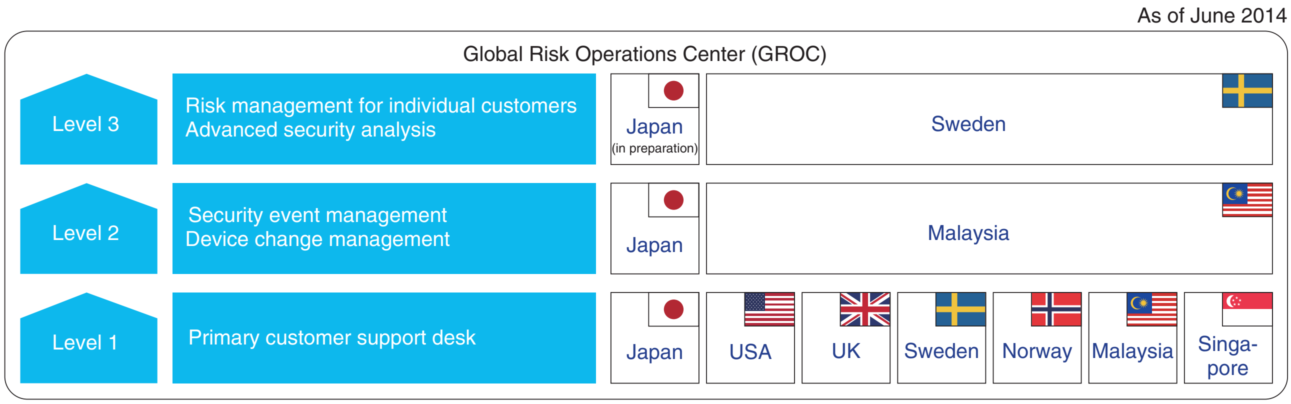

Fig. 5. Security monitoring operations system.

NTT Com Security began its security business in 1986 at overseas locations and in 2003 at the Tokyo SOC as a base within Japan. The company continues in its role of monitoring corporate network security. At present, a total of about 200 employees work at customer support desks at seven bases around the world (**Fig. 5**). This support includes security event management and device change management in Japan and Malaysia and advanced security analysis and risk management for individual customers in Japan and Sweden.

The company began providing Biz Managed Security Services as MSS for the Japan market in June 2012. In 2013, it upgraded its service platform under a new service brand called WideAngle to provide information security services for customer systems in a seamless manner across international and domestic cloud services and on-premise corporate systems. In this way, NTT Com Security can provide both corporate information security platforms and operations services as a trusted advisor. In MSS, the company provides total security outsourcing services on various layers to uncover vulnerabilities and deal with new types of threats such as targeted attacks that aim to exploit user psychology. NTT Com Security has come to manage over 11,000 security devices in about 3000 companies (as of May 2014).

At NTT Com Security, security consulting is the pillar of professional services, and the company has a record of providing consulting in more than 8000 cases over the last 25 years. Based on this extensive experience accumulated since its initial founding, the company is now providing a new consulting program called Global Enterprise Methodology (GEM). This program has established a globally uniform evaluation technique and systematized the company's know-how. It quantifies the security level of a client company, determines the optimal security level that the company should have given the client's business and industry and the requirements to attain that level, and makes proposals for overall improvement.

In information security, the defending side must be optimized in the face of ever-changing attacks. The attacker, meanwhile, may not necessarily be aiming to exploit information or engage in fraud through only one attack. A more likely scenario is that the attacker shifts to full execution only after making some preparations and performing a preliminary investigation of the target site. Detecting such signs of prior activity can only be accomplished through managed services that perform continuous security monitoring. An effective defense against attacks cannot be achieved by only implementing a countermeasure once, by only deploying security devices, or by only using a detection system engine.

It is extremely difficult for a company to thoroughly defend itself from threats by implementing such measures on its own or by keeping an eye on numerous devices.

The new WideAngle service platform provided by NTT Com Security features a newly developed security information and event management (SIEM) engine in addition to monitoring and analysis by expert risk analysts. It also provides the customer with a portal for integrated viewing of the state of various security devices.

In providing total managed services for client companies and public institutions, NTT Com Security is working with NTT laboratories, NTT DATA, and Solutionary to assemble knowledge and know-how related to NTT Group security technology. It researches how to identify threats that are continuously changing, how to protect information assets, and how to make the use of such assets safe. It then promptly incorporates the results of this research into actual services.

4. NTT Group's approach to security solutions

The NTT Group added Solutionary in North America as a new security service provider in 2013, and together with NTT Com Security (born out of Integralis and Secode), Earthwave, a subsidiary of Dimension Data, and NTT I^3, the Group's research and development center in North America, it has been making its presence felt in the global security market and receiving high marks from client companies.

The NTT Group was evaluated as a "Challenger" in Gartner's 2014 Magic Quadrant for Global MSSPs*, which positions MSS providers in the global market, and was positioned in the same quadrant as the vendor with the highest "ability to execute."

At NTT Com Security, we believe that the reason for this high evaluation is due to our provision of high-quality MSS services, our development of a wide variety of novel technologies in support of those services, our globally uniform system of providing services and operating SOCs, and our sophisticated information exchange network within the NTT Group for keeping up with the latest security trends and threats.

Going forward, we aim to create a synergetic effect through even further interaction and collaboration among the NTT Group companies while providing solutions in diverse domains such as network services, datacenters, and cloud services. Our desire is to provide cutting-edge security solutions at the forefront of the industry by working together as a unified group.

* Gartner, "Magic Quadrant for Global MSSPs," Kelly M. Kavanagh, 26 February 2014.
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Tetsuo Someya

Chief Business Development Officer and Chief Governance Officer, NTT Com Security.

He has an MBA from Yale School of Management and a BA in law from Waseda University in Japan. He was appointed Chief Business Development Officer and Chief Governance Officer in January 2013. As Chief Business Development Officer, he is responsible for developing the relationship between NTT Com Security and NTT Communications and its affiliates. In his role as Chief Governance Officer, he looks after key group governance functions, including those concerning legal, procurement, information security, internal auditing, and group IT issues.

Prior to this, he worked in a variety of roles across NTT Communications for over 20 years, including service planning and development, public relations, global business strategy, and global human resources management, and spent time at NTT Europe leading the Düsseldorf office. He also played an important role in overseas investment management at NTT (holding company) from 2001 to 2005.

Signal Generator for Noise Search Tester to Improve Noise-measurement and Noise-identification Skills

Abstract

This article introduces recent equipment and methods developed for use in troubleshooting noise faults. This is the twenty-fifth of a bimonthly series on the theme of practical field information on telecommunication technologies. This month's contribution is from the EMC Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters, NTT EAST.

Keywords: noise faults, noise measurement, maintenance skills

1. Introduction

The objective in the development of electric and electronic devices in recent years has been to make them smaller and more energy efficient. Meeting this objective, however, results in heavy use of the switching circuit in the power-supply section of such devices. This means that noise caused by the operation of the switching circuit or by problems in capacitors, semiconductors, or other circuit devices may be conducted to the outside via power or communication lines or radiated through space. Noise of this type can generate audible noise in telephone calls in the user's building or home or can bring down a communication link in ADSL/VDSL (asymmetric digital subscriber line/very-high-speed DSL) lines as a result of a communication coding error or other fault. In this situation, some type of countermeasure must be taken such as installing appropriate noise filters in the power or communication lines connected to the telephone equipment or by removing the noise sources themselves. In any case, measuring the frequency and levels of the disturbance voltage (or current) superimposed on power or communication lines is necessary for the troubleshooting process. It is for this reason that we developed a noise search tester (NST) that can be easily used by on-site maintenance operators. We have also marketed a successor to this product (NST II) that features enhanced sensitivity to periodic burst noise. More than 1000 units of the NST series have so far been introduced into the market.

In order to look for the noise source, it is necessary to conduct the noise measurement in complex facility environments that include not only telecommunication equipment but also various types of power-supply devices. It is therefore important that maintenance operators improve their skills in conducting measurements with NST II. In this article, we present a case study of a malfunction of telecommunication equipment and describe our development of a signal generator designed for simulating actual noise waveforms.

2. Case study

2.1 Noise sources

Noise sources that can lead to faults can exist in a wide variety of electric and electronic devices in addition to communications equipment. Identifying a noise source can therefore be quite difficult. Types of noise sources found in a two-year on-site survey are shown in **Fig. 1**. It can be seen from the figure that electric and electronic devices that use alternating current (AC) mains power, for example, a *Kotatsu* and AV (audio-visual) equipment, can be a source of noise. However, because a variety of electric and

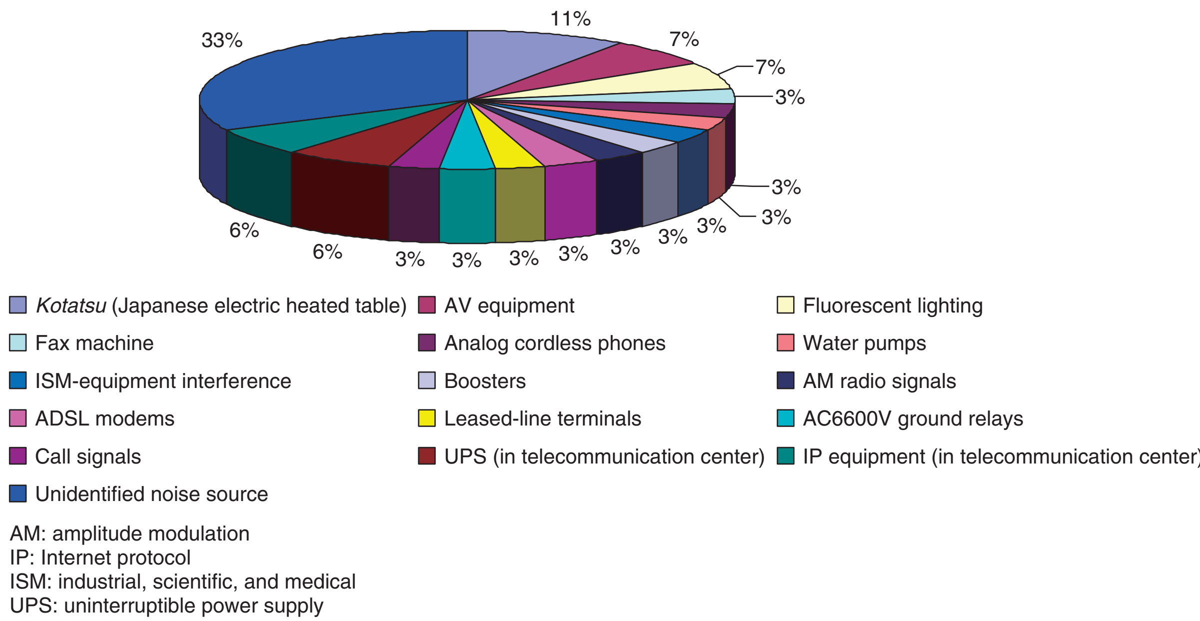

Fig. 1. Types of noise sources.

electronic devices are usually connected to the same AC mains line, it has been extremely difficult to identify where the noise source is actually located. The following section presents a case study of a noise-induced fault describing how the noise source was identified and what countermeasure was taken.

2.2 Case study of noise-induced fault

2.2.1 Fault overview

A customer using business phones reported a fault in which an audible noise would sometimes be heard during telephone calls. The facility setup on the customer's premises is shown in **Fig. 2**. Although a maintenance operator spoke with the customer a number of times to determine the cause of the fault, the fault remained, and it was eventually decided to perform on-site noise measurements and consider countermeasures.

2.2.2 Noise measurement

The maintenance operator performed noise measurements at several locations (points A–C in Fig. 2) and measured, in particular, disturbance current using an oscilloscope and current probe. The noise waveforms at the intercom communication line (point A) are shown in **Fig. 3**.

(1) The noise waveforms depicted typical periodic burst noise that was generated every half cycle (10 ms) with respect to the frequency of AC mains power (50 Hz). An on-site inspection revealed that this noise was generated when arc welding work was being done. It was also found that disturbance current values were highest on the intercom communication line (point A in Fig. 2) situated adjacent to the arc welding workplace.

(2) The results of performing FFT (fast Fourier transform) analysis on the measurement results of Fig. 3 and determining its power spectrum are shown in **Fig. 4**. In comparing the state in which noise was present with the state in which noise was absent, it was found that the noise level was high across a wide frequency range of 800 kHz–10 MHz.

These measurement results indicate that the fault occurred during the arc welding operation. In addition, the results of more detailed measurements revealed that this noise was transmitted to the business phone from the intercom communication line near the arc welding workplace, and it then flowed into other communication lines and AC mains lines.

2.2.3 Noise countermeasure

The following actions were taken as a countermeasure to this noise:

(1) Unused multi-pair in-customer-premises cables near the arc welding workplace were removed.

(2) Noise filters were installed on communication lines on the business-phone side and on the

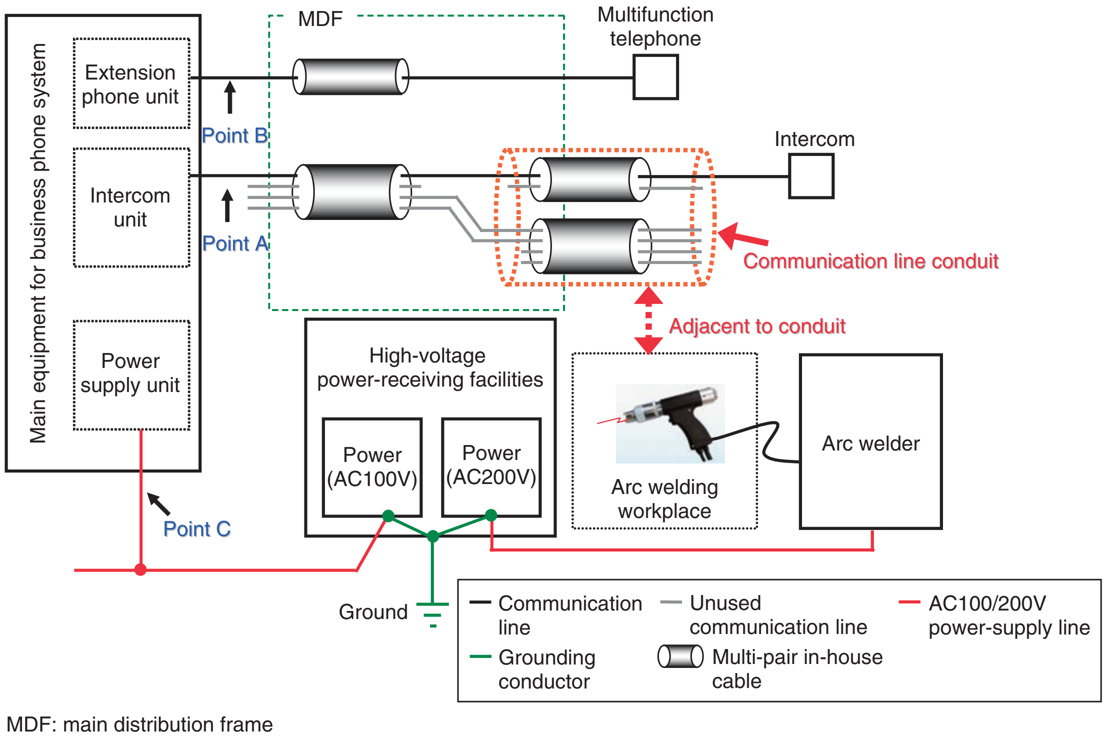

Fig. 2. Facility setup on customer's premises.

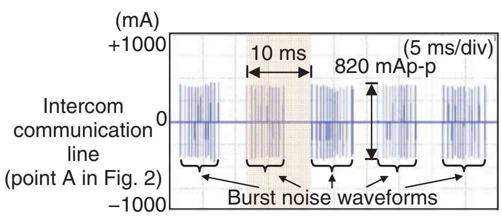

Fig. 3. Noise-current waveforms on intercom communication line.

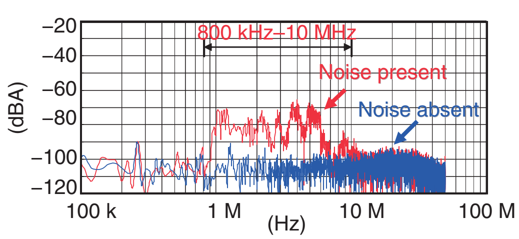

Fig. 4. Power spectrum of intercom communication line.

side of terminals connected to the business-phone side.

(3) A transformer was installed on the business-phone AC mains line; the ground terminal and the business-phone FG (frame ground) terminal were connected, and these were connected in turn to the MDF (main distribution frame) ground, keeping the connection as short as possible. The above countermeasure made it possible to eliminate the audible noise from the business-phone side.

Nevertheless, the on-site maintenance operator said that we had had few encounters with a noise-induced fault of this type, which meant that they had no opportunities to practice troubleshooting or dealing with this kind of problem, even employing an easy-to-use measurement tool like the NST II. We therefore realized that a tool that could facilitate the acquisition of necessary skills when using NST II had to be developed.

3. Signal generator for use with a noise search tester

3.1 Development background

Given the occurrence of audible noise in telephone calls or of link down in ADSL/VDSL lines, an experienced maintenance operator would be able to measure noise using NST II (**Fig. 5**) and then identify the source of the noise and implement appropriate countermeasures with noise filters. An on-site maintenance operator needs noise-measurement skills to appropriately identify the noise source and to select noise filters when using NST II. For this reason, we have been engaged in technology dissemination activities by creating a noise fault environment using a signal generator so that maintenance operators can acquire the skills needed for troubleshooting and identifying noise sources and for selecting appropriate countermeasures. Maintenance operators who have wanted to improve their noise-measurement skills on their own have been faced with a number of problems, which is reflected by comments received from them such as "Signal generators are too expensive" and "Creating a noise environment is too difficult." In the face of these problems, we developed a signal generator for use with a noise search tester that can easily and inexpensively create noise environments for training purposes (**Fig. 6**).

3.2 Functions

This signal generator has been designed to enable simulated noise to be safely and easily measured when used in combination with NST II. Two important points in the development of this signal generator are described below.

(1) Triangular-wave signals

The signal generator can output seven types of triangular-wave signals corresponding to the NST II frequency range. It was decided to use triangular-wave signals since the high harmonic components of noise cannot be simulated in the case of sinusoidal signals. The specific signal frequencies that can be output are 1 kHz, 15 kHz, 70 kHz, 250 kHz, 1 MHz, 3 MHz, and 20 MHz, which means that the signal generator can simulate signals that approximate those of actual noise waveforms (**Fig. 7**).

(2) Signals that simulate burst noise on AC mains line

The signal generator can output signals that simulate the periodic burst noise (half cycle of the frequency) on an AC mains line. This type of noise has become the chief cause of noise-related faults in

Fig. 5. NST II.

Fig. 6. Signal generator for use with a noise search tester.

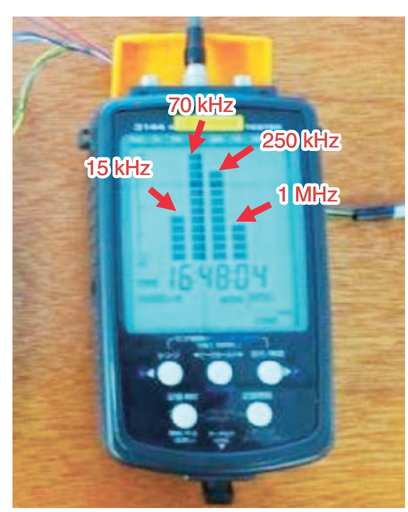

Fig. 7. Screen showing noise measurement for 70-kHz signal.

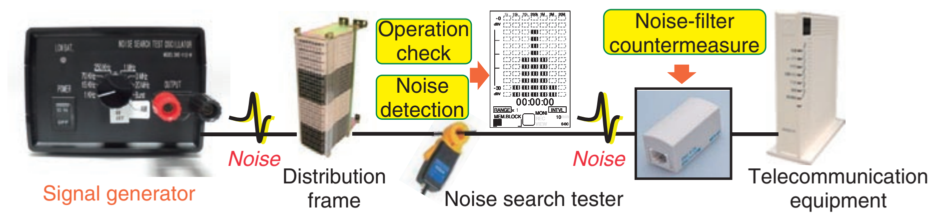

Fig. 8. Usage scenario.

recent years. When selecting a simulated noise signal, the user can listen to a whirring sound representing noise by connecting an earphone to the NST II for monitoring purposes.

The signal generator described above enables maintenance operators to improve their noise measurement skills using NST II by making it possible to easily create a noise environment that is similar to one with actual noise faults.

3.3 Usage of the signal generator

A typical setup for this signal generator, NST II, and telecommunication equipment is shown in **Fig. 8**. In this figure, the signal generator directly applies noise to the communication cable, and a maintenance operator uses NST II to measure that noise. By checking for the frequency of the NST II, the maintenance operator can apply an appropriate countermeasure. This signal generator therefore makes it easy to create an environment in which maintenance operators can practice searching for the noise source and decide what countermeasure to take against the noise fault, which has been difficult to do in the past. We expect repeated practice with such simulated noise to enable maintenance operators to solve noise faults on communication cables.

4. Conclusion

Solving noise-induced faults in a system requires troubleshooting skills in identifying the source of the noise as well as skills for taking appropriate countermeasures. To meet these requirements, we developed a signal generator for use with a noise search tester as an effective means of creating a noise environment at low cost and to enable maintenance operators to acquire noise measurement skills while using NST II. Going forward, we plan to continue our research and development efforts to facilitate speedy solutions to noise-related problems and provide enhanced support for safe and secure communication services.

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External Awards

Entropy Best Paper Award 2014, 1st Prize of Review Award

Winner: Katherine L. Brown, School of Physics and Astronomy, University of Leeds; William J. Munro, NTT Basic Research Laboratories; and Vivien M. Kendon, School of Physics and Astronomy, University of Leeds

Date: April 30, 2014

Organization: Multidisciplinary Digital Publishing Institute (MDPI) AG, based in Basel, Switzerland

For "Using Quantum Computers for Quantum Simulation".

In this review we surveyed the theoretical and experimental development of quantum simulation using quantum computers, from the first ideas to the intense research efforts currently underway. This was the first comprehensive review.

Published as: K. L. Brown, W. J. Munro, and V. M. Kendon, "Using Quantum Computers for Quantum Simulation," Entropy 2010, Vol. 12, No. 11, pp. 2268–2307.

Papers Published in Technical Journals and Conference Proceedings

Network Coding and its Application to Content Centric Networking

S. Miyake and H. Asaeda

Proc. of WITMSE (Workshop on Information Theoretic Methods in Science and Engineering) 2013, pp. 55–61, Tokyo, Japan, August 2013.

Content Centric Networking (CCN) is one of the predominant proposals that have been made for the next generation content distribution platform. In CCN each router in a network is equipped with a large sized cache memory and becomes a content router that can be regarded as a temporary content server in the network. This mechanism can reduce the concentration of data traffic going into the original content server.

To enhance the merits of CCN, we propose applying network coding (NWC) to it. Applying NWC in this way makes it possible to implement distributed data storing of content data and to achieve multi-path transmission between content routers and an access router (or an end user). CCN with NWC can provide higher throughput for end users and reduce network load.

In addition to proposing the aforementioned application, in this paper we specify issues needing to be addressed to more successfully combine CCN with NWC.

A Disaster Resilient Image and Video Transmission Scheme Based on Movable and Deployable Resource Units

T. Nakachi, S.Y. Kim, and T. Fujii

Proc. of HTC (Humanitarian Technology Conference) 2013, IEEE Region 10, Sendai, Japan, August 2013.

In this paper, we propose a disaster resilient image and video transmission scheme based on specially designed "Movable and Deployable Resource Units (MDRUs)". The proposed resilient data transmission scheme offers image and video data appropriately to people in disaster areas through MDRUs. The image and video data are transmitted based on the MDRU power supplies and the network bandwidth between the MDRUs and terminal devices in the disaster area. Experimental results and demonstrations show the effectiveness of the proposed disaster resilient image and video transmission scheme.

A Conceptual Foundation of NSCW Transport Design Using an MMT Standard

T. Nakachi, Y. Tonomura, and T. Fujii

Proc. of ICSPCS (International Conference on Signal Processing and Communication Systems) 2013, Gold Coast, Australia, December 2013.

This paper introduces the concept of Network Supported Collaborative Work (NSCW) and its transport design based on the emerging standard of MPEG Media Transport (MMT). Based on extra-high quality 4K video technologies, NSCW is being developed to realize effective remote collaboration for business workspaces. MMT specifies technologies for the delivery of coded media data for multimedia services over the concatenation of heterogeneous packet based network segments including bidirectional IP networks and unidirectional digital broadcasting networks. One of the core technologies for delivery is forward error correction (FEC) codes. Simulation results using our proposed MMT FEC codes show the effectiveness of the proposed method.

An Overlay Network Construction Technique for Minimizing the Impact of Physical Network Disruption in Cloud Storage Systems

K. Suto, H. Nishiyama, N. Kato, T. Nakachi, T. Fujii, and A. Takahara

Proc. of ICNC (International Conference on Computing, Networking and Communications) 2014, pp. 68–72, Honolulu, HI, USA, February 2014.

Cloud storage exploiting overlay networks is considered to be a scalable and autonomous architecture. While this technology can ensure the security of storage service, it requires addressing the "server breakdown" problem, which may arise due to malicious attacks on servers and mechanical problems with servers. In existing literature, an overlay network based on bimodal degree distribution was proposed to achieve high connectivity to combat these two types of server breakdown. However, it cannot ensure the high connectivity against physical network disruption that removes numerous nodes from the overlay network. To deal with this issue, in this paper, we propose a physical network aware overlay network, in which the neighboring nodes are connected with one another in the overlay. Moreover, the numerical analysis indicates that the proposed system considerably outperforms the conventional system in terms of service availability.

An Iterative Compensation Approach without Linearization of Projector Responses for Multiple-projector System

I. Miyagawa, Y. Sugaya, H. Arai, and M. Morimoto

IEEE Transactions on Image Processing, Vol. 23, No. 6, pp. 2676–2687, June 2014.

We aim to realize a new and simple compensation method that robustly handles multiple-projector systems without recourse to the linearization of projector response functions. We introduce state equations, which distribute arbitrary brightness among the individual projectors, and control the state equations according to the feedback from a camera. By employing the color-mixing matrix with gradient of projector responses, we compensate the controlled brightness input to each projector. Our method dispenses with cooperation among multiple projectors as well as time-consuming photometric calibration. Compared with existing methods, our method is shown to offer superior compensation performance and a more effective way of compensating multiple-projector systems.

Water Electrolysis and Energy Harvesting with 0D Ion-sensitive Field-effect Transistors

N. Clément, K. Nishiguchi, J. F. Dufrêche, D. Guérin, A. Fujiwara, and D. Vuillaume

Proc. of International Symposium on Energy Challenges & Mechanics, Aberdeen, Scotland, UK, July 2014.

Water electrolysis is one of the most "green" approaches for producing hydrogen (H_2) as a fuel source. As a key issue in the operation of the International Space Station and the mission to Mars, water electrolysis is utilized as a regenerative life support system and is part of the energy conversion system. The behavior of gas bubbles in water electrolysis is a typical interfacial phenomenon. Many experiments including optical, acoustic, and other approaches (e.g., electrical impedance), have been performed to determine the bubble size distribution in samples of water. Here, we show that nanotransistors, which are so small that they can be considered as 0D, can be used to transform energy lost during bubble emission into electrical pulses. This system does not require light, is sensitive to a single bubble, and has no intrinsic limitation in bubble size.

Rapid Switching in High-Q Mechanical Resonators

H. Okamoto, I. Mahboob, K. Onomitsu, and H. Yamaguchi

Applied Physics Letters, Vol. 105, 083114, August 2014.

Sharp resonance spectra of high-Q micromechanical resonators are advantageous in their applications, such as highly precise sensors and narrow band-pass filters. However, the high-Q characteristics hinder quick repetitive operations of mechanical resonators because of their long ring-down time due to their slow energy relaxation. Here, we demonstrate a scheme to solve this trade-off problem in paired GaAs micromechanical resonators by using parametrically induced intermode coupling. The strong intermode coupling induced by the piezoelectric modulation of tension allows on-demand energy transfer between closely spaced mechanical modes of the resonator via coherent control of the coupling. This enables rapid switching of the vibration amplitude within the ring-down time, leading to quick repetitive operations in high-Q mechanical resonators.

On the Computational Power of Constant-depth Exact Quantum Circuits

Y. Takahashi

Proc. of Satellite Workshop of AQUIS (Asian Quantum Information Science Conference) 2014, Tokyo, Japan, August 2014.

We show that there exists a constant-depth polynomial-size quantum circuit for the quantum OR operation. We also show that, under a plausible assumption, there exists a classically hard problem that is solvable by a constant-depth quantum circuit with gates for the quantum Fourier transform.

Hardness of Classically Simulating Quantum Circuits with Unbounded Toffoli and Fan-out Gates

Y. Takahashi, T. Yamazaki, and K. Tanaka

Quantum Information and Computation, Vol. 14, No. 13&14, pp. 1149–1164, October 2014.

We show that there exists a constant-depth quantum circuit with only one unbounded Toffoli gate that is not weakly simulatable, unless $BQP \subseteq PostBPP \cap AM$. Then, we show that there exists a constant-depth quantum circuit with only two unbounded fan-out gates that is not strongly simulatable, unless $P = PP$.