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SYSTEMS AND APPLICATIONS ENGINEERING FIBRE-OPTICS TECHNOLOGY

(PHASE II)

DP/IND/85/074

INDIA

Technical report: Fiber-optics special applications promotion program (FOSAPP)*

Prepared for the Government of India

by the United Nations Industrial Development Organization,

acting as executing agency for the United Nations Development Programme

Based on the work of A.B. Sharma, expert in fiber-optics applications in the service sector, railways, power, and FOLANs for office automation

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Vienna

* This document has not been edited.

ABSTRACT

After a synopsis of the background leading to the initiation of this project, and the sub-projects that have been identified by the execution team, this report evaluates the present status of the project and the facilities available for its implementation. Based on the interaction of the expert with the engineering teams, recommendations for furthering the project have been made, and some possibilities for future work have been identified.

The main conclusions are that although many improvements in the R&D infrastructure are required, the project is appropriate for the two centers involved, and that the expert is confident of the successful completion of the tasks undertaken.

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1. Introduction

Since the advent of the low loss (20 dB/km) optical fiber at the beginning of the 1970's, impressive progress has been made in terms of the loss of the fiber, it's information-carrying capacity, and it's price. Today, the loss minimum of the fiber is below 0,2 dB/km, transmission rates (limited essentially by the available electronics technology) in single-mode fibers in excess of 2,4 Gbit/s have been demonstrated, while prices are definitly competetive with copper cables even in absolute terms. As a consequence, world-wide deployment of optical-fiber telecommunication systems is in progress. This is also reflected in the activities in India as examplified by fiber and cable production by Hindustan Cables Ltd and OPTEL (a Madhya Pradesh State enterprise) concurrent with systems design and implementation by the Telecom Research Laboratories of Indian Telephone Industries Ltd.. However, in spite of the prime importance of telecom (voice) application, it is expected by considered opinion in India that within the next five years at least 50% of fiber-optic applications will be within the non-voice area. Of relevance are local computer networking, data-transmission links, industrial control systems, dedicated communication networks such as for railways, optical fiber sensors (transducers), as well as video transmission. In the industrial world (and presumably in the developing world), these demarcations are likely to become diffuse in the 1990's, with the emergence of ISDN and BISDN, but do roughly-speaking hold today.

Within the above framework, the aim of the present project is precisely the promotion of these non-voice and industrial applications by building up indegenous expertise in India, and by acquainting electronic-equipment manufacturers and potential end users with the advantages of

fiber-optics technology. As detailed in Job Description DP/IND/85/074/11-01/J13313, and repeated here for convenience, the aim in the immediate term is to:

1.1 build up three groups of engineers in the above-mentioned areas, each group to consist of (as pointed out by the Indian joint coordinators) representatives from an R&D organization, an electronic-equipment manufacturer, and an end user;

1.2 develop fully-engineered experimental systems in the same areas;

1.3 carry out cost-benefit studies to establish techno-economic advantages;

1.4 train Indian scientists and engineers as a resource base for future R&D;

1.5 create a data base for design-methodologic use by interested parties both in India and abroad.

The duties of the expert were to (a) interact with the Indian project execution teams located in Delhi, Hyderabad, and Kota (Rajasthan); (b) to jointly prepare detailed working plans for the engineering teams; (c) to advise on the latest design practices, application areas, components, sub-systems etc., and (d) to prepare a final report setting out findings and recommendations.

The program of work was carried out between October 27, 1988 and January 31, 1989 including travel time and excluding a seven-day vacation for the expert which was partly used for the preparation of the preliminary draft of the final report. At the request of the joint coordinators the expert also agreed to attend and present a series of lectures at the UNDP sponsored "Workshop on Fiber-Optic

Applications for Industrial Automation" (March 6-11, 1989 Hyderabad) and to visit IIT-Kharagpur, an institution closely associated with the FOSAPP project. The relevant itenerary is outlined in Appendix 1, including the days for briefing and de-briefing in Vienna, and the time associated with travel to and within India. Time spent in Delhi was mainly for coordination meetings with the joint coordinator at the Department of Electronics, and administration-related visits to the UNDP offices. The technical activities were mainly carried out in Hyderabad and Kota, with visits to IIT-Madras which is closely associated with ECIL (Electronics Corporation of India Ltd.). Interaction with ECIL-Madras was also useful in that the expert was brought into contact with potential end users.

As such, after this introduction and the recommendations that follow, this report is divided into two main sections describing separately the work and findings of the expert (a) for ECIL-Hyderabad and (b) for Instrumentation Ltd. (IL) Kota. Conclusions related to the activities of each of these centers are included at the end of each section.

2.0 Recommendations

Since the final broad-term definition of this project took shape some time ago in 1985, a major consideration for the expert on this , his first, mission was to update himself, in consultation with the joint coordinators, on the actual sub-projects that the Indian execution team had identified for implementation. Besides the technical input, which came as a natural part of the interaction with the engineering teams, a second major motive was to survey the available facilities, as well as academic back-up. Expressing his confidence in the appropriateness and viability of the undertaken tasks, the following observations might be useful for building a stronger R&D base, particularly in the long term.

2.1 Because of the multi-disciplinary nature of the undertaken fiber-optics tasks, there is a need for further training via workshops in India and hands-on training in industrial countries abroad.

2.2 Certain general-purpose electronic equipment, discussed later in the report, needs to be purchased. This is to facilitate characterization of prototypes. The differing needs of the two FOSAPP centers are discussed later.

2.3 Both centers would find it useful to have more general-purpose optical instruments to facilitate various measurements, and to rapidly try out systems ideas. This would also require a laboratory equipped with optical rails, tables, manupulators, and bulk optics.

2.4 Both centers would find it useful to improve their

library facilities by subscribing to the most important professional journals. This would keep the R&D engineers in touch with the latest developments.

2.5 A feasibility study to assess the possibility of the indegenous fabrication of optical fiber sensors and couplers should be followed up.

As a result of informal discussions during the experts stay at the two centers, some of the actions outlined above are already being followed up, but others may require UNDP financial support.

3.0 Electronic Corporation of India Ltd. (ECIL).

The main interest of this FOSAPP center is in distributed control as well as monitoring operations by exploiting FOLANS. The company is also involved in telecom-related activities e.g. PCM terminal equipment, and can, therefore, provide potential support for the UNDP-sponsored activities. The ongoing activities are headed by Mr. T.N. Swamy with Mr. G.R.K. Rao acting as the technical coordinator. The salient projects are outlined below.

3.1 Fiber-Optical Analogue Video Link

The engineer responsible for the design and development of this link (intended for industrial monitoring purposes)is Mrs. S.N.V.Vani, and she presently has an existing laboratory demonstration. So far, link characterization is essentially qualitative mainly because of lack of required instrumentation (e.g. a spectrum analyzer). However some measurements were possible by using existing equipment; for example the signal-to-noise ratio was estimated by using an oscilloscope on the video signal. In the absence of signal-dependent noise, the noise level could be estimated by applying synchronization pulses only (zero signal). By the time of the expert's departure, and given the constraints, reasonable steps had been taken to better quantify the performance of the system. It is the author's understanding that some of the missing key instruments (also required by the other FOSAPP projects discussed below) are already on order, but further financial support may be necessary for completing the basic infra-structure of the laboratory.

3.2 Fiber-Optical Digital Video Link

This project is in the early stages of design and development, and is presently suffering from the common difficulty within the group of inexperience in the design of high-frequency analogue and digital electronics. This problem was in part alleviated via tutorial and experimental interaction with the expert, and will be further attacked during the three-month training (beginning May 1989) period at the expert's laboratory in Finland. However, further UNIDO support may be required to completely overcome this difficulty.

3.3 Point-to-point Optical Fiber Links

Three engineers (M.V.S. Kiran, M.S. Khan, K. Sudir Kumar) are involved in this project in which the purpose is to design systems for 5 to 125 Mb/s operation. They are presently envisaged to be a PIN-LED configuration with a "TAXI-chip" providing an NRZ-5B6B line code with inversion on alternate logic ones. These links are intended for computer-to-terminal applications. Once again, difficulties related to high-speed electronics exist and should be eased by appropriate training.

3.4 Fiber-Optic Token-Ring LAN for Distributed Control

The experimental version of this system has been implemented by a group of three engineers (K. Sudir Kumar, P.K. Kondaiah, Ms. N.M. Gowri), and is presently being used by the Control Group within ECIL. The work appears to be well-in-hand, and, indeed, the expert only marginally interacted on this project.

3.5 Railways Applications

The design work for this project is being carried out at the Indian Institute of Technology (IIT-Madras) under the leadership of Profs. Raina and Jhunjhunwala. The work is still incomplete, but it is anticipated that the productionization agency will be ECIL-Hyderabad. The immediate coordination on the part of ECIL is being handled by Mr. R. Venkateswarlu, who is acting as the technical manager of the project. The expert was led to understand that delays on this project are expected, partly because of change of staff at the IIT, and partly because Indian Southern Railways have not so far committed themselves as to the final specifications. However, it is known that the fiberoptic system will operate at 2 Mb/s (PCM) and is to span a distance of 5 km. The system will connect a master station to 3 slave stations and will be used for track switching, axle counting (no. of carriages past sensor), signalling, as well as for carrying three voice channels.

3.6 Conclusions

Upon the request of the joint coordinator, Mr. T.N. Swamy, and in collaboration with the technical coordinator, Mr. G.R.K. Rao, the first half of the time spent at ECIL-Hyderabad was devoted to a critical and in-depth "dissection" of all the FOSAPP-related projects. This process, involving direct discussion with the engineers responsible for actual design and construction, was found to be very useful in that it gave the expert the oppurtunity to become personally acquainted with the engineers, as well as their approach to circuit design and implementation. This period was followed by practical involvement in partial re-designs and circuit improvements. During this period, the expert also presented two series of lectures to acquaint the group with current international trends and likely future systems. Based on this close involvement, the expert was left in no doubt as to the high calibre of the engineers and the firm support given to them both by top management and their immediate group leaders.

During the expert's practical participation in each project, a noticeable feature was insufficient characterization of final designs. This was partly due to a lack of certain equipment, but also because the engineers lack a background in analogue electronics, an essential feature for receiver design. In order to fill this and other related gaps (e.g. in systems theory and fiber optics) the expert feels that workshops and seminars for further education, and more training courses in industrialized countries, should be organized on a regular basis for a few years, in full appreciation of the inter-disciplinary nature of optical fiber communications. The group has reasonable "clean -laboratory" facilities, but infra-structure improvement is required in terms of the purchase of research laboratory

optical equipment that can be flexibly adapted for other uses.

Although India is some years behind the spearhead of international effort, it is felt by the author that although a "quantum leap" is in theory possible for ECIL (based on the calibre of its R&D engineers and management), this is probably not, as yet, wise because a successful leap may require a stronger and more flexible technical infra-structure. The present FOSAPP programs are realistic and should be used to create the necessary spring board that could be used after a few years to attain, and in select areas even to lead, developement efforts. In the meantime, it may also be worth-while to take up projects on labour-intensive components (e.g. couplers) which tend to be expensive in the industrial world. Production of some types of optical fiber sensors may also be an appropriate way of exploiting the know-how that is building up.

4. Instrumentation Ltd., Kota

This FOSAPP center, directed by the general manager of R&D, Mr. M.K. Tewari, consists of six engineers: Messrs. A.K. Jaiswal (technical manager), Kapil Solanki, Gurubaksh Singh, S.N. Gupta, Sanjiv Kesari, and M. Gupta. It is important to understand that the group is relatively new and is as such still in the earlier stages of acquiring expertise in fiber-optics engineering. The expert's activities were, therefore, somewhat different in nature at this center, and were mainly directed towards familiarizing the group with the use of essential equipment, transmitter and receiver design principles, as well as procedures related to splicing and connecting fibers and cables. The exception was the initiation of one product-development activity that is central to the steel-plant process-control application that the center has as a goal (see 4.4).

The expert was stationed at IL-Kota from January 4, to January 27, 1989, and interacted with the group of engineers in the following main areas.

4.1 Use of an Automatic Fusion Splicer

A commercially available machine for splicing multimode and single-mode fibers has been acquired by the group. The machine is automatic in the sense that after introduction of the fibers to be spliced, the following steps are processor controlled, and the operator is guided through the total procedure step by step. The machine also provides an estimate of the splice loss for one particular type of fiber. However, proper use of the machine requires careful pre-alignment, well cleaved fiber ends, careful introduction into the machine, as well as cleaniness discipline through out. An additional problem that was faced was that the manufacturer had not provided any information on the estimation of splice losses for an arbitrary fiber.

Activities concentrated on the development of procedures for cleaving fibers, machine alignment, and the splicing itself, including procedures related to microscopy at all relevant stages. A simplified theory for the on-line estimation of splice loss was also formulated. The theory was tested experimentally based on the measurements described in 4.2, and a procedure was established for estimating the loss of any fiber. The generated set of instructions turned out to be highly successful in that even inexperienced members of the group could produce low-loss splices.

4.2 Measurement of Splice Loss

The stability of the available optical sources and power meter was extensively measured to ensure sufficiently low invariance over the period of time required for the measurement of splice loss. Integration times were also established in order to achieve the required signal-to-noise ratio. The source and detector facilities of the splicing machine were also tested in the same manner. Both sets of equipment were then used for establishing optical power levels before and after splicing, and thus to obtain the loss. This information was then used to calibrate the splicing machine according to the theory mentioned in 4.1.

4.3 Assembly of SMA Connectors

The group has also acquired commercial equipment for the assembly of SMA-type connectors. Procedures were estblished for the preparation of fibers, their introduction into the connector shells, subsequent bonding, strain removal, and polishing. Good commercial grade connectors were obtained, and this assembly procedure may be considered to be well in hand.

4.4 Design and Construction of 10 Mb/s Transmitter and Receiver Prototypes

The group had developed a low-speed (9.6 kb/s) link based on an LED transmitter and a PIN receiver, and had faced difficulties in higher speed operation. At the request of the joint coordinator (M.K. Tewari) and the technical manager (A.K. Jaiswal), the expert gave informal tutorials on factors that need to be taken into account in the design, layout, construction, and characterization of high-speed circuits. In support of this, an experimental 10 Mb/s transmitter was designed and constructed, and the construction of the corresponding receiver was initiated. However, the work could not be completed because of a lack of availability of certain key components. Characterization also remained incomplete due to lack of appropriate instrumentation. Further UNIDO assistance may be required in order to alleviate the difficulties.

4.5 Conclusions

Based on the close involvement with the design engineers at this FOSAPP center, the expert feels that the group is building up the important capability for field installation of optical cables, although there is still some way to go before the procedures become routine. The group also has available a good facility for the speedy fabrication of printed-circuit boards. Because the profile of this center is naturally inclined towards instrumentation, it is felt by the expert that further support is required in terms of training and further education related to fiber optics and high-speed (particularly analogue) electronics. As in the case of the FOSAPP center at ECIL, this could be done via workshops held in India, via training courses abroad, as well as via more intense interaction with a suitable IIT. The establishment of a fiber-optics related library facility

would also be important in order to be able to follow developments in the field and to encourage self-study. The group also requires further support in terms of appropriate electronics instrumentation such as high-speed signal generators, oscilloscopes, spectrum analyzers. Given the background of IL-Kota it may also be appropriate for the center to also be involved in other non-voice activities such as optical fiber sensors. However, it may be advisable to first build up fiber-optics know-how within the framework of this process-control project, which on the whole seems appropriate for this group, albeit recruitment of a few higher calibre engineers might be desireable in order to further strengthen the group. Towards this same end, it is to be recommended that an infra-structure comprising dust-free laboratories equipped with general-purpose optical and electronics equipment, and a sufficiency of key components be set up as speedily as possible.

APPENDIX I

ITINERARY

26 October, 1988	14.45 Tampere-Helsinki 17.00 (Train)
27 October, 1988	10.10 Helsinki- Frankfurt 11.50 12.40 Frankfurt-Vienna 14.00
28 October, 1988	Full day briefing in Vienna
29 October, 1988	10.25 Vienna-Amsterdam 12.10 17.20 Amsterdam--->
30 October, 1988	-----> Delhi 06.25
31 October, 1988	Briefing at UNDP Delhi
1 November, 1988	Consultations with FOSAPP joint coordinator at DOE. Visit to fiber-optics group at IIT-Delhi
2 November, 1988	06.20 Delhi-Hyderabad 08.05 (Delayed)

2 November, 1988 to 29 November, 1988 stationed at ECIL

30 November, 1988	07.45 Hyderabad-Delhi 09.30 (delayed) afternoon visit to UNDP offices
1 December, 1988	Coordination meeting at DOE
2 December, 1988	06.20 Delhi-Hyderabad 10.05 flight delayed by over 5 hrs.. IIT visit postponed.

5 December,1988	Visit to FOSAPP center at IIT-Madras
5-9 December, 1988	Vacation
12 December, 1988	Lectured to potential of fiber-optics to end users at ECIL-Madras
13 December, 1988	06.00 Madras-Delhi 09.45 (delayed) afternoon meeting with joint coordinator at DOE. Rquested to spend further time at ECIL-Hyderabad.
14-16 December, 1988	Vacation; preparation of preliminary draft of final report
17-20 December, 1988	All flights and trains to Hyderabad fully booked.
21 December, 1988	17.00 Delhi----->
22 December, 1988	------>Hyderabad 15.00
30 December, 1988	10.20 Hyderabad-Madras 11.35
2 January, 1989	Meeting at IIT-Madras
3 January, 1989	06.00 Madras-Delhi 09.45 Visit to UNDP offices. Reported findings to the joint coordinator at DOE
4 January, 1989	17.00 Delhi-Kota 22.00

5-27 January, 1989	Stationed at IL-Kota
27 January, 1989	07.20 Kota-Delhi 09.40 (no saturday flight)
29 January, 1989	03.30 Delhi-Frankfurt-Vienna 10.20
30 January, 1989	De-briefing at UNIDO
30 January, 1989	17.30 Vienna-F'furt-Helsinki 00.40
31 January, 1989	10.00 Helsinki-Tampere 12.10 (train)