Some Implications of Telecommunication Policies in Developing Countries

BIRENDRA PRASADA, MEMBER, IEEE

Abstract—In developing countries telecommunication policies are based on the urban development program. It is pointed out that the telecommunication needs of the developing countries lie in both the urban and rural areas and as a result two distinct networks, urban and rural, are needed. Establishment of a National Rural Telecommunication Agency is suggested to implement the concept of rural networks.

INTRODUCTION

THE present telecommunications policies in developing countries derive from considering telecommunication services primarily as an urban consumption item for the industry and its government. The importance of telecommunications as an input to the rural development programs that represent a major effort in all developing societies is not emphasized in the present planning. For example, in a country like India 80 percent of the population live in rural areas without adequate telecommunication facilities.

In general, in the urban sector the development process tends to be characterized in purely economic terms such as savings, investments, outputs, unemployment and demand and supply and prices. In the rural areas where peasants have lived in a subsistence agriculture oriented economy for generations the success of a development process is dependent on communicating a growth perspective [1]. There is greater acceptance that the development process cannot only be characterized in purely economic terms, i.e., in terms of creation of wealth. As a matter of fact, greater equality is a precondition for lifting the society out of poverty [2]. In the developing countries, economic development is only a means to social goals and aspirations such as closing the gap between the elite and the common people [3]. This paper emphasizes the development of a rural telecommunications network to satisfy the needs of rural population. It emphasizes the role of communications in the development process, briefly outlines, as an example, India's telecommunications network and then discusses communication needs of rural areas. Based on these needs some design considerations and system possibilities are outlined.

The Role of Communication in Development

Communication is a prerequisite for development. Rao [4] has pointed out that when information comes to an isolated community, it triggers changes. He holds communication as a big contributor towards development. He further observes that if the channels of information are varied, the changes triggered by them are smooth. Lerner [5] sees communication as a great multiplier of ideas and information for national development. He has also observed a very high correlation between measures of economic growth and those of communication. Deutsch [6] concludes that communication can do much in bringing social coherence, in weaving people and regions together. In a developing country the fundamental problem is to persuade the people to adopt new ideas, techniques, social relationships and to inculcate desired attitudes and attributes. New ideas are not automatically accepted; they require education and training. Astute use of communications can greatly help these processes [7].

Tanner [8] has pointed out the dangers of too much one-way communications (mass media), and has urged the development of telecommunications for the establishment of feedback channels. Schramm [9] has emphasized the need for two-way communications so that the needs, concerns, and achievements of various communities can be communicated upwards and outwards. Teer [10] states that while the mass media can reach large numbers, telecommunications spread participation and are operationally stimulating. Myrdal [2] points out that most developing nations profess egalitarian ideals. To become important, these ideals need pressure from below—something that is missing in most developing countries.

Hudson and Parker [11] state that telecommunicatious services can play important roles in rural development. They observe that at the present time, telecommunication is treated as an urban consumption item and is designed to maximize economic return for the entrepreneurs. Thomson [12], [13] points out that evaluation of communication innovations in a society is more complex than the simple notion of profit for the investor. He suggests that important communication innovations alter the environment in which the system is embedded and open up whole new ways of creating wealth.

INDIAN TELEPHONE NETWORK

The Indian telephone network, which has grown from 82 000 telephone lines in 1948 to 1 590 000 in 1974, is primarily a nodal network interconnecting the state capitals and large cities. About five percent of the population in 13 major cities account for more than half the telephone sets in the country. [14]. The other cities and towns account for most of the other telephones. Recently, there has been some penetration in smaller towns; however, the rural areas have hardly any service. The planners perceive the Indian network as an urban service "for the operation of business, administration, defense, etc." [15]. In the forecasts for the 1980's

Manuscript received December 31, 1975; revised February 6, 1976. This paper is based on the author's familiarity with the Indian scene and uses India as a case study. However, the approach and conclusions are applicable to most of the developing countries.

The author is with the Department of Electrical Engineering, Indian Institute of Technology, Kanpur, India.

[16], it is predicted that "major expansion (in telephone networks) will continue to be in urban areas in exchanges with individual capacities of more than 1000 subscribers." In the forecasts, very casual and tentative references are made to rural telecommunications. In the "Ten Year Profile for Electronics and Communications" [15], rural communications find reference only in the sixth plan under the miscellaneous heading of "other likely services." As long as the telecommunications services are planned as an urban service for industry and government, the present plans and projections make eminent sense. However, the communication needs of 80 percent of the population in rural areas are not reflected in the present plan.

COMMUNICATION NEEDS OF THE RURAL AREAS

The information needs of rural and urban populations are different because of different vocations and existing levels of knowledge [17].

The requirements of communications for a community can be organized in a hierarchy [18], namely:

1) International
2) Continental
3) Regional
4) National
5) State
6) Local
7) Interpersonal

The more developed a community is, the higher in the hierarchy its communication requirements reach. For rural areas, the interaction span is generally limited to the nearby villages, the subdivisional town, and sometimes to the district headquarters. Thus, the telecommunications requirements rarely go beyond the local level in the hierarchy. Some of the specific areas in which telecommunications might be useful in the rural areas are the following.

1) Health Care: The delivery of health care in rural areas of all developing countries is far from adequate. There is a shortage of doctors and their reluctance to live in rural areas further reduces the availability of medical services. The introduction of rural telecommunication networks will provide the services of the doctor to a larger number of people through paramedical personnel. The doctors serving in rural areas will be able to discuss cases with doctors in the urban and district hospitals and will not feel isolated. As a result, more doctors may feel inclined to accept rural assignment. Specialized services such as mobile X-ray vans can also be scheduled for visits through the rural telecommunications network.

2) Access to Markets: In villages, the farmers obtain fertilizer, seeds and other requirements from shops or cooperatives located in small towns or large villages. Telecommunication services will help the rural areas in obtaining reliable information about price, availability and other matters.

3) Participation in the Planning and Development Process: Suitable communication techniques can lead to participation of the villages in planning of the development projects that affect their lives, thus ensuring the success of these projects. Tanner [19] suggests the design of a lateral communication system for encouraging and facilitating the discussion of issues among the people so that each consensus is the result of well-informed thinking. With the help of a proper communication network, the village councils in the neighboring villages will be able to discuss projects in their areas with the project coordinator.

4) Education: A large-scale experiment called Satellite Instructional Television Experiment (SITE) is currently being conducted in India to beam developmental programs to a few thousand remote Indian villages [20]. SITE has instructional objectives in the fields of agriculture, family planning and education, especially pertaining to rural development. This experiment is likely to be followed by continuing developmental education by television and radio. Feedback channels which can be provided by rural telecommunications network can considerably increase the efficacy of this type of educational project.

5) Emergency Information: Emergency information on flood, fire, epidemics, etc., can be sent on the rural network so that they can be broadcast by the local radio station.

6) Requirements of the Change Agents: The extension workers who live in the rural communities can be used more effectively with the help of the rural network. Based on the fourth five-year plan of Uttar Pradesh, Owen [21] points out that there are 112 000 villages to be contacted by agricultural extension workers. Each worker has to help 600 to 1000 families spread over 10 to 12 villages. Within the time and resources available, it is not possible for the worker to approach each family even once a year. Availability of two-way communications will provide access to the villager who can contact the change agent on his initiative also, be they paramedical workers or animal husbandry workers or agriculture extension workers.

DESIGN CONSIDERATIONS

Having established the need for rural communications, we will review the following basic design considerations.

1) Geographical: Communication is to be provided between villages that are somewhat isolated because of lack of transportation and communications. It must be pointed out that at least in the Indo-Gangetic plains where more than half the Indian people live, the communities are separated only by small distances unlike the cases in Alaska, Canadian North, and Australia, where the population density is small and the isolated communities are separated by vast distances.

2) Social: The requirements for communication is mostly local to the nearby villages and to the small towns in the area. There may be infrequent need to interconnect to the urban network. Communications between a group and an individual or between several groups may be needed more than individual person-to-person communication. Since most of the communication will be development oriented, privacy is not a prime requirement. As a matter of fact, experience in Alaska with "doctor calls" [11] shows that much may be gained if other interested persons have access to the conversation.

3) Economical: The pricing of the service has to be such that it encourages people to use it. Since villages are poor, the rate structure has to be far from compensatory.

SYSTEM POSSIBILITIES

Thomson [12] states "that communication innovations that are high in conviviality and are also consensus builders appear to directly impinge upon the processes that are basic to the wealth creating means of a society." Hudson and Parker [11] have translated the development needs into three main design requirements, namely:

1) intraregional communication capability,
2) conference call capability, and
3) accessibility.

Among the possibilities, extension of the urban telephone network to rural areas will not meet the developmental requirements and will be very expensive. Telex with low bandwidth service has several limitations for rural requirements. It is not interactive; it does not meet the accessibility requirements and cannot transcend the illiteracy barrier. (The government of India plans to install 5000 new offices for the rural network [22].)

Hudson and Parker have preferred a satellite based system. For a given satellite power, there is a tradeoff between the number of channels and the cost of the ground terminal. For a high-power satellite, the cost of the ground terminal can be brought down in the range of \$2500 to \$7500, if the number of channels is reduced to a few (~15). This alternative has proven very attractive in providing communications to thinly populated and widely separated places in the Pacific [23].

Some of the concepts and technologies of mobile radio communications can be useful [24], [25]. Since the communication requirement is mostly local, by putting a transponder on a 200-meter tower and using multiple access techniques, communications can be provided in a radius of about 20 miles. Frequency reuse can be planned as in the mobile communication systems. In the Indo-Gangetic plains, nodal points of the urban network may be made available every 40 miles or interconnecting points can be created for the rural network so as to connect one rural transponder to another. Radiotelephones can provide immediate service in most of the areas.

At this time, there is a need for experimentation rather than blueprint of a single design. In the light of the needs and environment, concepts such as Comminterphone,[1] radiotelephone, transponder on tower, multiple access systems through satellites, and conference type telephone sets should be explored and tested in the field wherever possible.

To organize the research and development work and subsequently to design and implement the rural network, it is necessary to assign a separate budget and possibly a separate organization. A National Rural Telecommunications Agency should be created. This agency could be totally autonomous or could be a part of the Posts and Telegraphs Department.

The rural network cannot be funded from the present budget of the urban network or from its revenues. The National Rural Telecommunications Agency must have a separate budget which comes from funds assigned for rural development. It will have to work very closely with the various state governments. Since the rural network will be a decentralized network, planning and implementation can begin with states which are more enthusiastic about the possibilities.

[1] In the Canadian arctic, a new communication technique called the Community Interaction Telephone (Comminterphone) [26] has been designed to encourage community involvement through the combined use of telephones and radio. By dialing a certain number, the individual conversations can be broadcast over a low-power AM transmitter over a radius of five miles. Listeners can join by dialing and up to four persons can participate.

CONCLUDING REMARKS

In a developing country, there is a rural–urban dichotomy. It is proposed that the developing nations should consider setting up an autonomous rural telecommunications network quite distinct from the urban network in terms of facilities, characteristics, services pricing, and accessibility.

Once the development planners accept the need for two distinct networks, the utilization of radio spectrum resource should be reviewed. At the present time, most of the spectrum is assigned for services to defense, industry, government, and railways. Radio spectrum is a development resource and the rural sector must get a fair share of this resource.

The need is stated for research, development, system studies, and field trials of various concepts and technologies relevant for rural telecommunications.

REFERENCES

[1] W. Schramm and M. Winfield, "New uses of mass communication for the promotion of economic and social development," UNESCO (E).

[2] G. Myrdal, *The Challenge of World Poverty.* New York: Penguin Int. ed., 1970.

[3] B. Prasada and J. P. Singh, Eds., "Advanced system for communications and mass education for India's development," Indian Institute of Technology, Kanpur, India, Final Rep., June, 1969; condensed version published in *Communication Satellite Systems for the '70's*, A.I.A.A. Series Progress in Astronautics and Aeronautics, vol. 26. Cambridge, MA: M.I.T. Press, 1971, p. 101.

[4] Y. V. L. Rao, *Communication and Development: A Study of Two Indian Villages.* Minneapolis, MN: Univ. Minnesota Press, 1966.

[5] D. Lerner, *Passing of the traditional society.*

[6] K. Deutsch, *Nationalism and Social Communications.* Cambridge, MA: M.I.T. Press, 1953.

[7] B. Prasada and J. P. Singh, "Television, education and communications: Software considerations," presented at Roundtable Conf. D, 11th World Congr. Soc. Int. Development, Washington, DC, New Delhi, India, Nov. 14–17, 1969, Paper 6.

[8] R. H. Tanner, "On man's needs for communication," *IEEE Trans. Commun. (Special Issue on Interactive Broadband Cable Systems)*, vol. COM-23, pp. 3–5, Jan. 1975.

[9] W. Schramm, "Communications and development process," *Develop. Dig.*, Oct. 1966.

[10] K. Teer, "Communication and telecommunication," *IEEE Trans. Commun. (Special Issue on Social Implications of Telecommunications)*, vol. COM-23, pp. 1040–1045, Oct. 1975.

[11] H. E. Hudson and E. B. Parker, "Telecommunications planning for rural development," *IEEE Trans. Commun. (Special Issue on Social Implications of Telecommunications)*, vol. COM-23, pp. 1177–1185, Oct. 1975.

[12] G. B. Thompson, "An assessment methodology for evaluating communications innovations," *IEEE Trans. Commun. (Special Issue on Social Implications of Telecommunications)*, vol. COM-23, pp. 1045–1054, Oct. 1975.

[13] G. B. Thomson, "Moloch or Aquarius," *The*, issue 4, Feb. 1970.
[14] "The World's telephones as of January 1, 1974," published by Overseas Administration, AT&T Company, Dec. 1974.
[15] "Ten year profile for electronics and communications," *Electron. Inform. Planning*, vol. 1, p. 160, Nov. 1973.
[16] T. S. Subramanian, "Development of public telecommunications–Technology forecast for 1980's," in *1974 IEEE Conf. Rec.*, Annu. Conv. and Exhibition, 74 CHO 957-1, India, p. 112.
[17] K. V. Sarabhai, "Satellite for national rural development communications system," unpublished note, Aug. 1972.
[18] B. Prasada, "Communications in Asia: Problems and prospects," presented at One Asia Assembly, Press Foundation of Asia, Manila, Philippines, Apr. 11, 1970.
[19] R. H. Tanner, "Guest Editorial," in *Telesis No. 2*, vol. 4, p. 33, Summer 1975.
[20] Y. Pal, "Some experiences in preparing for a satellite television experiment for rural India," in *Proc. Royal Soc. of London*, vol. 345, p. 493, Oct. 1975.
[21] W. Owen, "Distance and development: Transportation and communication in India," The Brookings Institute, Washington, DC, 1968.
[22] "The Indian subcontinent," *ITU TeleCommunications J.* (Editorial), vol. 42, p. 128, Mar. 1975.
[23] J. W. Bystrom, "Use of satellites to support communications," in *Proc. Royal Soc. of London*, vol. 345, pp. 431–610, Oct. 7, 1975.
[24] W. C. Jakes, Ed., *Microwave Mobile Communications.* New York: Wiley, 1974.
[25] M. Jacobsen, "Public car radio telephone service," *Teleteknik* (English Edition), vol. 18, no. 2, 1974.
[26] "Restoring community to Arctic communications," *Telesis No. 4*, vol. 2, p. 28, Spring 1972.

★

Birendra Prasada (M'63) is Professor of Electrical Engineering at the Indian Institute of Technology, Kanpur. His main teaching and research interests are in the areas of Systems Engineering Systems Design, Visual Communications, and Human Communications.

From November 1973 to February 1976, he was a member of the Technical Staff of the Electronics and Computer Systems Research Laboratory, Bell Laboratories, Holmdel, NJ. He has served as the Head of Electrical Engineering Department (1968–1972) and Head of the Advanced Center of Electronic Systems (1972–1973) at the Indian Institute of Technology. He was on the faculty at the Massachusetts Institute of Technology, Cambridge, in 1965–1966. He was a member of the Technical Staff at Bell Laboratories, Murray Hill, NJ, during 1963–1965. He worked at the Central Electronics Engineering Research Institute, Pilani, India and Defense Science Laboratory, Delhi, India, during 1961–1963. He has consulted for industries in India and the United States.

Choice of Technology for Rural Telecommunication in Developing Countries

HENRY CHASIA

Abstract—This paper draws attention to the outstanding feature of present telecommunications in developing countries, namely that most of the equipment is installed in towns but most people live in rural areas.

Various features of the social environment are outlined, indicating their importance for planning and choice of technology. Social change is shown to offer the opportunity for telecommunication development but it also poses the main challenge to planning.

The paper outlines the main constraints to choice of technology, emphasizing those that relate to the socioeconomic environment in the rural areas. Within these constraints, a pragmatic approach is advocated which admits both old and modern technological solutions. A discussion of the technology-transfer question develops a conceptual framework within which this approach may be justified.

Manuscript received December 22, 1975; revised February 19, 1976. This work is based on an unpublished Ph.D. dissertation entitled "The Role of Telecommunication in East African Development," submitted by the author to the University of London, London, England, in July 1974, and was supported in part by the International Telecommunication Union. The opinions expressed in this paper are the author's and do not necessarily reflect the views of INTELSAT.

The author is with the International Telecommunications Satellite Organization (INTELSAT), Washington, DC 20024.

I. STATEMENT OF THE PROBLEM

A. Introduction

TELEPHONE networks in developing countries typically conform to a standard pattern: most of the equipment is installed in urban centers whereas the overwhelming majority of the population live in rural areas. This pattern is the outcome of various factors, social, economic, political, etc., which have combined to create a climate favorable for the development of telecommunications in the urban centers but not in the rural areas.

The demand for telecommunications in the rural areas is low; such demand arises in small pockets which are generally widely separated and therefore expensive to satisfy. Because the service is expensive, demand is inhibited and therefore service continues to be expensive, *mutatis mutandis.* Although the demand is low, the need is strong because the various agencies and institutions required for rural development need telecommunication for the conduct of their everyday business.

The initial requirement is therefore for a telephone network to meet the needs of government in the area of administration and security. Additionally, the network should provide the communication requirements of public services in fields such as education, health, land tenure, and agriculture. These services form part of the expanded role of government in the rural areas, offering a pool of information and advice to assist development.

This paper discusses the problems involved in planning a telephone network for the rural areas with particular attention to the choice of appropriate technology.

B. The Social Context of Technology Choice

In the past it has been generally considered that the choice of technology for telecommunications in Third World countries was something apart from their conditon of underdevelopment. The technologist has paid only peripheral attention to development matters, being content to define his mission in developing countries as merely that of constructing systems to cope with the physical and climatic conditions in these countries. What society did with technology, or what technology did to society has not appeared to be a matter of legitimate concern to him.

In such circumstances, it is hardly surprising that technology should be conceived as something neutral to development and the task of technology transfer as that of making modification to equipment so that it may suit the different physical and climatic conditions in the Third World.

It has become clear that technology transfer is basically a social process. Many of the assumptions embodied in the design of equipment reflect social conditions in the countries where and for which the equipment was originally made. The transfer of such equipment from one social environment to another may violate these assumptions and affect its operation.

II. TECHNOLOGY ENVIRONMENT

1) In the present environment, developing countries have the opportunity to consider old and modern technologies from various manufacturers throughout the world in making their choice. Some developing countries also have the capability to develop technologies of their own, which are uniquely suited to their needs. Through published literatnre, the services of consultants, and organizations such as the International Telecommunication Union (ITU), developing countries may avail themselves of the experience of developed countries in many fields of telecommunication.

In principle then, the technology environment appears to be a favorable one, offering developing countries a wide range of choices. Moreover, without the encumbrance of large investments in existing networks, they have the opportunity to apply fresh thinking to their problems, to avoid pitfalls which developed countries were able to recognize only after the fact, and to choose only those technologies which suit their circumstances.

2) The telephone network itself has certain characteristics which have a compelling influence on decisions pertaining to technology choice.

The first feature of the telephone network is that it is extensive in space, serving people in homes and work places. It is intitmately associated with the space relationships inherent in human settlements. Associated with the space properties is the network's essential feature of iuterconnectedness. Each telephone must be connected to millions of other telephones. This requires an enormous network which must be properly organized to provide desired transmission quality through complex signaling and routing. The extensiveness in space, complexity, and interdependence suggest that the network must be conceived on an overall, rather than on a piecemeal, basis.

The second feature is that decisions concerning the choice of telecommunication technology have a very long impact time—equipment installed today will most likely still be in operation after the year 2000. A further consideration is that, in general, telecommunication equipment is installed to suit a particular community and to move such equipment is not only expensive, it is liable to cause damage; while operation in a different locality may be unsatisfactory.

III. SOCIAL ENVIRONMENT

1) The organization of any society depends on the means of communication available to it. Rural society in Third World countries is organized on the basis of personal contact and face-to-face communication. While face-to-face communication promotes group and neighborhood cohesiveness, it is incapable of sustaining the more flexible organizations which characterize developed societies. In such organizations, social relationships are impersonal and membership is generally large and widely dispersed; their communication requirements therefore involve such means as the post, newspapers, and telecommunication.

The process of development involves the creation of new forms of organization which require the support of modern communication facilities of which telecommunication is an important component. Early provision of telecommunication in the rural areas helps development by offering channels for the rapid dissemination of "modernizing" ideas, by facilitating more effective government and efficient deployment of the various development agencies operating in rural areas. Telecommunication is an asset to the development effort because it is rapid, efficient, and relatively cheaper than other communication facilities.

2) Development in the rural areas is also accompanied by changes in the pattern and location of human settlements. New settlements may be established by deliberate policy of governments or spontaneously by rural people as they seize new opportunities necessitating change of location. Some Third World countries have developed "physical plans" which provide for the use of land, the movement of people and goods, patterns of production and residence, distribution of

the physical infrastructure. Such plans are generally only indicative offering an informal reference point for those involved in infrastructural planning but providing no firm or inflexible guidelines.

The telecommunication planner in developing countries therefore faces an uncertain situation with regard to the evolution of rural settlement patterns. However, the purpose of infrastructural planning is to help mould these patterns through careful identification of "growth poles", i.e., locations which may be provided with communications and other services. The availability of superior communications attracts increasing agglomeration which, in turn, justifies additional communications, etc. [1], [2].

The availability of telecommunication at growth poles also provides a nucleus from which the cultural impact of the telephone may diffuse into the surrounding area [3], [4]. The initial telephone subscribers are normally from government and institutions; at a later stage, as rural inhabitants appreciate the value of this innovation, the requirement for telecommunication would arise spontaneously from private subscribers.

IV. TECHNOLOGY CHOICE

A. Constraints Upon Technology Choice

1) General Factors:

a) The choice of technology can only be exercised within the scope of the available resources: In relation to the allocation of resources, political factors determine the level of priority placed on rural telecommunications in relation to: i) the competing claims for improvement in urban telecommunications, and ii) the competing claims of other items of infrastructure such as transportation, health, water resources, education, etc.

b) The choice of technology is circumscribed by the stipulations of foreign financing arrangements: Telecommunciation development in Third World countries is characterized by bilateral and multilateral financing arrangements. An important feature of these arrangements pertains to the approach to the rate-of-return criterion. Since investments in rural areas are not generally expected to yield a return for many years, it is nor easy to find the necessary finance from foreign sources. On the other hand, it is relatively easier to attract finance for urban and interurban telecommunications. Therefore, it is fair to say that the effect of foreign finance *so far* has been to widen the cleavage between the rural and nrban areas in the field of telecommunications.

c) The choice of technology is influenced by technology choices which have been made in the past: Because of the interconnected nature of the telephone network, any new equipment must be capable of interworking with equipment already in operation. If not, expensive interfaces may be required. Moreover, new technologies require new skills and the need for retraining. Mixed technologies necessitate varieties of test equipment and stores holding. The advantages of standardization tend to operate in such a way as to limit the scope for choice of new technology.

2) Social Change: Social change creates difficulties in forecasting requirements. Developed countries have the advantage of a long history of records which help to identify trends. This is not the case in the developing countries; however, it is important to stress that records alone do not spell the difference; the problem is much more fundamental, concerning the relationship between the telephone and institution-creation. Traditional forecasting methods which rely on macroindicators make the implicit assumption the institutions exist and that there is an ongoing interaction between them and relecommunications. When one cannot make this assumption, one is unable to forecast.

The second aspect of social change has to do with location changes. Location changes have serious implications for telecommunication planning because telephone exchanges are designed for specific locations. When conditions change in such location, the equipment may have to moved or modified. Otherwise, the exchange will not operate efficiently.

3) Inadequate Infrastructure: The telephone is being introduced alongside, often much in advance of, other infrastructural development. Many items necessary for the installation and operation of the telephone service, such as transportation, supplies, main power, and technical skills, are generally inadequate and often lacking.

B. Attributes of the Chosen Technology

1) Cost Effectiveness: Cost effectiveness is an essential attribute of the chosen technology because of the shortage of funds for rural telecommunications. Initial prices are important, but an important consideration is the high cost of operation and maintenance of a network in rural areas. Moreover, cost effectiveness has to be reflected in the organization and layout of the network to achieve maximum benefits for each dollar invested, e.g., reaching greater numbers of people or a greater area of coverage. Different technologies offer different facilities and since these facilities may not all be capable of quantification in monetary terms, value judgments are necessary.

2) Power and Maintenance Limitations: Rural electrification generally lags behind telecommunication development. In most areas mains power does not exist. A similar constraint applies to maintenance requirements. The requisite skills and necessary supplies may not exist in the immediate locality. The choice of technology will therefore be heavily weighed in favor of equipment with low power consumption, low fault liability, and no on-site repair work.

3) Reliability: Reliability has to be considered from two viewpoints. Firstly, in rural conditions, unreliable telephone service will not encourage the rural population to organize its affairs round the use of the telephone. Therefore, the system must be well-maintained and dependable. However, reliability involves more than just good maintenance. To provide safeguards against breakdowns the network needs to have certain topological features ensuring diversified routing.

These safeguards cost money and the question is whether the additional expense can be justified. In the initial stages, network configurations based on the "minimum spanning tree" [5], though highly insecure, may nevertheless be adequate. Security may be improved with increasing subscribers and traffic demand.

4) Flexibility: Social change in its various manifestations has one main implication for technology, namely flexibility. But flexibility has a price and therefore the search for flexibility must be accompanied by efforts to minimize its cost penalties. Two kinds of flexibility are required.

The first kind of flexibility is required to deal with changes in the time domain, such as inaccuracies in forecasting subscriber requirements and the need for interworking with new technologies. The second type of flexibility is required to cope with changes in conditions affecting location.

Two approaches to the flexibility problem may be cited. The first is based on container technology. Telephone equipment is installed in a container which is then transported on wheels to site. No elaborate preparations of site are required beyond bringing in subscriber's cables. If for some reason the location is subsequently found to be unsuitable, the container can be wheeled to a new location. In this way, the problem of inaccurate forecasts or changes in subscriber or traffic patterns may be obviated. However, no mobile exchange can be fully versatile and often these exchanges operate inoptimally because they are designed to cater for average rather than specific conditions.

Stored-program systems constitute a second approach. In these systems, the basic design and hardware featnres are independent of the particular installation. Features specific to a given installation are held in easily alterable software. Moreover, a modular structure is envisaged, minimizing the variety of basic units and permitting growth in regular steps without disruption to what is already installed and working. An additional feature is that a number of widely scattered switch units may be remotely controlled from a central processor. The remote units may be kept especially simple. Conceptually, the system is well-suited to the flexibility requirements of rural conditions in developing countries. Neverthless, cost and maintenance requirements need to be reviewed.

C. Considerations Relating to Technology Transfer

An important concern in discussions of choice of technology for developing countries relates to the need for labor-intensive techniques. Is this a legitimate objective of planning for rural telecommunications? It is to be remarked that the direct impact of a rural telephone network on rural employment is likely to be exceedingly small. At this stage, the overriding need is for good communication and therefore the objectives of the plan need not be unduly complicated by considerations relating to employment.

A further concern is often expressed by the view that developing countries must seek out the older forms of technology in the first instance and then move on to the more advanced technologies in imitation of the historical pattern followed by the developed countries. In some respects, this argument is not unreasonable: the older equipment is generally less complicated, requiring a lower level of technician skills. Moreover, older equipment may have been designed for light traffic and few subscribers, whereas modern equipment is designed for large subscriber concentrations and large quantities of traffic.

However, the older equipment may have been superseded precisely because the newer techniques were cheaper, more efficient, and even simpler. In such circumstances it would be unreasonable to go for old technologies for the sake of conforming to a precept. Indeed, it is likely that the older technologies may be a maintenance liability on account of the difficulty of securing spare parts.

The advocates of outdated technology, as well as those like Schumacher who advocate a middle way or an "Intermediate Technology" [6], are much concerned with the quest for relevance in terms of the social environment. In relation to the rural environment, telecommunication is in every way an "advanced" technology. Even the older forms of the technology do not form part of the sociotechnological milieu of rural society. This is not, however, to say that the technology is not required or that it could not function in that environment.

The transfer process can be viewed in terms of the adjustment of the society's institutions to the technology. This adjustment may be conceived at three levels. The first is the ability to *use* the technology. In regard to telecommunications, it has already been argued that the need already exists and, in the light of the various activities concerned with rural development, this need will grow steadily to embrace all institution users and, through innovation diffusion, bring in private users as well.

The second level of adjustment is the society's ability to acquire the skills necessary to *operate and maintain* the technology. This is the crucial element in the choice of telecommunication technology for a developing country. A distinction must be drawn between the requirements of technology transfer at this level and those of the first level. In the first level it is anticipated the technology would in time be accessible to the majority; at the second level, it is only necessary that a group of people, perhaps only a very small proportion, can be found who can be taught the skills required to keep the equipment in operation.

The third level of adjustment requires the society to have the necessary cultural and institutional structure enabling it to *invent and make* the technology. The approach of this paper has not been based on this level although it is appreciated that some Third World countries already have the institutional base permitting technology transfer at this level.

V. CONCLUSION

From the foregoing discussion, the basis for choice of technology for rural telecommunication in Third World countries is not simply a decision between old and modern, labor-intensive or capital-intensive technologies. The decision should be based on suitability of the given equipment of the socioeconomic conditions in rural areas, specifically those pertaining to cost, operation, and maintenance.

ACKNOWLEDGMENT

The author would like to thank his supervisor, Professor E. C. Cherry of Imperial College, London for guidance and encouragement.

REFERENCES

[1] M. Chisholm, *Rural Settlement and Land Use.* Hutchinson Univ. Library, 1968, p. 49.
[2] B. J. Garner, "Models of urban geography and settlement location," in *Models in Geography,* R. J. Chorley and P. Hagget, Ed. Methuen, 1967, p. 304.
[3] T. Hagerstrand, *Innovation Diffusion as a Spatial Process.* Chicago, IL: Univ. of Chicago Press, 1967, p. 264.
[4] D. Schon, *Beyond the Stable State.* London, England: Temple Smith, 1971, p. 82.
[5] H. Frank and I. T. Frisch, *Communication, Transmission and Transportation Networks.* Reading, MA: Addision Wesley, 1971, pp. 192–210.
[6] E. F. Schumacher, *Small is Beautiful, A Study of Economics as if People Mattered.* London, England: Blond and Briggs, 1973, pp. 152–177.

★

Henry Chasia was born in Maragoli, Kenya, on February 17, 1940. He was educated at Makerere College, Kampala, Uganda, and received the B.Sc. degree in physics and mathematics and the Ph.D. degree in electrical engineering from London University, London, England. From 1969–1974 he held an ITU fellowship at Imperial College, London.

He joined the East African Posts and Telecommunication Corporation in 1964, where his responsibilities included telecommunication development, traffic engineering, and network planning. The Corporation operates a telecommunication network covering three African coutries, Kenya, Tanzania, and Uganda. Since 1974 he has been a member of the technical staff of the Internationat Telecommunication Satellite Organization (INTELSAT) in Washington, DC.

Telecommunication Development–The Third Way

SATYAN G. PITRODA, MEMBER, IEEE

Abstract—The object of this paper is to define the *third way* to telecommunication development–suitable to the needs and conditions of the third world countries. It begins with some comments on the present conditions, identifies probable reasons, and defines three fundamental goals for developing nations: 1) rural communication, 2) accessibility, and 3) reliability. Based on these three goals, the third way to telecommunication development is defined. The need for an autonomous telecommunication technology center for the third world is emphasized, and its objectives, organization, and implementation are discussed.

A need for new systems geared toward increasing accessibility is advocated. As an example, a new concept called the "community telephone" is introduced, which is designed to provide reliable telecommunication service to a small community. At the end, it is concluded that the real implication of the third way to telecommunication development can only be analyzed through further interdisciplinary research.

I. INTRODUCTION

PRACTICALLY all of the developing countries of Asia, Africa, and Latin America have been colonized in the past, directly or indirectly, by a few of the industrialized countries. With few exceptions, present development programs in the third world countries are based on the framework of social, political, economic, and technological institutions that these countries inherited from colonial rule. The programs emphasize industrialization aimed at producing a high gross national product (GNP) growth rate. The telecommunication development in these countries is also based on the models inherited from the industrialized nations. In fact, the telecommunication equipments and practices designed for use in the developed countries are also being used in the developing countries.

The problems confronting the third world countries are many and require immediate attention. For any meaningful contribution, the telecommunication programs must consider the needs of rural areas where over 70 percent of the population live in poverty, suffering malnutrition, illiteracy, and unemployment. At the same time, these programs must be based on the third world models that take into consideration limited capital resources and virtually unlimited manpower.

It is believed that telecommunication has a significant contribution to make in developing countries where large-scale participation at all levels by *all people* is necessary for rapid development. However, in its present form, telecommunication in developing countries is used by a small privileged class and serves only business and government.

Manuscript received November 7, 1975; revised March 9, 1976.
The author is at 800 Enterprise Drive, Oak Brook, IL 60521.

The object of this paper is to define a *third way* to telecommunication development—adopted to the needs and conditions of the third world countries. It begins with some comments on present conditions, identifies probable reasons, and defines three fundamental goals: 1) rural communication, 2) accessibility, and 3) reliability. Based on these three goals, the third way to telecommunication development is defined. The need for an autonomous telecommunication technology center for the third world is emphasized, and its objectives, organization, and implementation are discussed.

A need for new systems geared toward increasing accessibility is advocated. As an example, a new concept called the "community telephone" is introduced, which would provide reliable telecommunication service to a small community. At the end, it is concluded that the implications of the third way to telecommunication development cau only be completely analyzed through further interdisciplinary research. However, the time is running out, and the work has to begin now.

II. THE PRESENT SITUATION

The present situation of telecommunications in developing countries can be analyzed by reviewing existing applications and problem areas.

A. Applications

Telecommunication technology in developing countries has been applied to service industrial and governmental organizations in order to increase production and ensure social and political order. It has also been applied as an urban consumption item. The pricing policy has been designed to discourage demand by requiring heavy initial investment. As a result, only the rich and elite can afford telephone services. Chasia [1] draws attention to the outstanding problem of existing telecommunications in developing countries, namely, that most of the equipment is now installed in cities whereas people live in rural areas. It is estimated that over half of the telephone sets in most developing countries are in a few metropolitan cities having less then 10 percent of the population. The telephone density of urban areas is considerably higher than the rural areas.

The use of coin-operated public telephones in developing countries is minimal. The ratio between private and public telephones in developing countries is not known. In developed countries, the ceutral office is normally designed with less than 1 percent coin-operated trunks. Since much the same switching systems are used in developing countries, it is estimated that the ratio is over 1 to 100, i.e., 1 public phone for over 100 private phones. For example, in India, there are over 500 000 villages with about 120 000 post offices and only 20 000 telephone offices. In many developing countries, the private phone is used as a public phone service by many shops and restaurants.

B. Problem Areas

The problems related to telecommunication in developing countries can be characterized by a disorderly evolntion of rapidly growing networks, which are congested and lack performance. These problems can be divided into two groups: 1) planning and 2) performance. The planning problems are administrative and include forecasting methods, determining demand patterns, pricing policies, service features, technological dependence, etc. Wellenius [2] calls these the problems of method. Planning problems also include implementation activities such as the introduction of modern management techniques, automation, standards, etc. Since systems in developing countries are acquired without overall national network planning by pnrchase, production, or as gifts (aid programs), the planning problem is aggravated by the introduction of incompatible systems from different manufacturers.

Performance problems directly affect the user and are ultimately manifested in available services. Performance problems include long waiting periods for dial tone, repeated dialing effort, frequently lost calls, multiple connections, and poor voice quality. The problems related to billing, maintenance, etc. are also considered performance problems.

Existing applications and a long list of performance problems show that telecommunication in developing countries provides unsatisfactory performance and only limited access. Telecommunication service has not yet reached the largely illiterate rural population. For them, verbal communication is the only way to communicate. It is this population that needs to be mobilized for development from the bottom (at the microeconomic level). It is assumed that the present state of telecommunication is undesirable and an alternative is needed. Before an alternative approach can be suggested, the reason behind the present conditions needs to be understood.

III. REASONS

The present state of telecommunication results from a variety of interactions at all levels, from planning to production. As a result, it is difficult to clarify the reasons for particular problems. However, it needs to be emphasized that the preseut state of telecommunications in developing countries results from a long history of imported equipments and technology. These imported equipments are designed for conditions existing in industrialized countries, and their appropriateness to developing countries has been questioned. The following two cases illustrate the appropriateness aspects of imported systems.

In one Asian country, an imported common control crossbar type exchange was selected after careful feasibility studies and long negotiations. During the first cutover, after several catastrophic failures, it was recognized that the traffic generated from the subscriber was considerably higher than the system could handle. The average calling rate varied from 10 to 16 busy hour calls per line. The trunk traffic, due to repeated attempts was found to be as high as 36 busy hour calls. The fact that low telephone density in a highly populated area generates high traffic per line was overlooked. The usual response of administration was to deload the system and order additional equipments.

It should have been recognized that switching systems in industrialized countries are designed to serve areas with high traffic density. Normally, these areas have one phone per home having three or four family members and generate low per line traffic. The situation in developing countries is exactly the opposite. The telephone density is low. As a resnlt, one phone is used by many people and the traffic generated per line is high.

In an African country, an imported modern communication system was found to drop calls regularly. After careful analysis, it was learned that the interdigital pause was too short. The designer had assumed user experience in dialing. The local population had no experience in dialing and required a large interdigital time. The system had to be modified to incorporate these variations.

In both cases, the appropriateness of equipment manufactured in developed countries should have been analyzed by the local administration. It is the prime responsibility of the recipient administration to see that the ultimate benefits of the new equipment and all technological ventures are compatible with the national requirements and goals. However, these recipient administrations generally lack knowledge, not only in the area of technology, but also in the area of applications, and are unable to provide a precise and coordinated policy and program.

Based on these and several other cases, it seems that totally imported technology without any local design participation necessary to obtain appreciation for applications and capabilities is one of the reasons for the present telecommunication problems in developing countries. The other reason is that the telecommunication planning in developing countries is based on an industrialized model that is designed to increase telephone density by providing private telephones in every home. This approach is not practicable in developing countries where resources of time, technology, and capital are limited.

A considerable amount of capital investment in facilities, such as telephone instruments, carriers, and switches, is associated with each telephone line, and it is desirable to use it effectively when capital is limited. It cannot be overemphasized that the private telephone approach is unsuitable for developing countries. It is only suitable for industrialized nations with sufficient capital and resources.

Besides these two fundamental reasons, 1) totally imported technology and 2) emphasis on telephone density, there are several other reasons which contribute to the overall inadequacy of telecommunication in developing countries. These include: lack of standards, lack of training, limited capital resources, limited technical manpower, etc. Because of the problems and associated reasons, it is desirable to define the basic telecommunication goals of developing countries.

IV. BASIC TELECOMMUNICATION GOALS

There are three basic telecommunication goals for a developing country: 1) rural communication, 2) accessibility, and 3) reliability.

A. Rural Communication

The need for rural communication has been emphasized by Prasada [3]. In a majority of the developing countries, the national development plans, such as agriculture, housing, and industries, are aimed at rural growth. However, their telecommunication plans do not emphasize rural growth and as a result, are not consistent with other national programs and policies.

B. Accessibility

As mentioned earlier, the telecommunication planning in developing countries is designed to satisfy a long list of waiting customers, thereby increasing telephone density. It is generally believed that the telephone density is related to the GNP of a country and any increase in it is prestigious because it represents national development and a growth in telecommunications. In reality, what is important is not the total number of phones or the telephone density of a country, but rather the accessibility of telephones. The telephone network should be readily accessible to majority of the population. It should be noted that to have guaranteed access to a telephone, you should not need to own one. Accessibility can be provided to a large community at minimum cost by providing one telephone line.

C. Reliability

Once the access to a telephone line is available, it is important that the access be reliable and result in call completion with a minimum of interruptions and delays. It is also important that the call provide noise-free conversation irrespective of the distance. It is recognized that high reliability requires considerable maintenance and diagnostic abilities. However, for any favorable public acceptance, this high reliability is imperative.

Some administrations in developing countries believe that it is economically sound to use old equipment and apply a huge work force to keep this equipment maintained. This idea results in an added benefit by reducing unemployment in highly populated developing countries [4]. This approach is strictly based on economics and does not take into consideration the social acceptance of telecommunication facilities by a rural population.

V. DEVELOPMENT THE THIRD WAY

Based on the present situation and related reasons, it has become absolutely clear that the third way to telecommunication development in developing countries should be aimed at three primary goals: 1) rural communication, 2) accessibility, and 3) reliability. The third way is different from the present technology that emphasizes urban communication and private phones.

Beside these three primary goals, the third way to telecommunication development takes into consideration three secondary objectives that are based on conditions in developing countries: 1) labor-intensive programs, 2) capital sensitivity, and 3) self-reliance.

A. Labor-Intensive Programs

One of the main resources in a developing country is its virtually unlimited, largely unskilled manpower. The telecommunication development program in developing countries should be designed to use this available manpower. Unfortunately, technologies that use plenty of labor and little capital are poorly documented and in many cases, nonexistent. The mass-production-oriented, labor-saving, capital-intensive, and highly complex technologies are well documented and easily available in industrialized countries. However, the laboratories in industrialized countries and their staff members are not oriented toward development of labor-intensive products, processes, and programs. As a result, developing countries have no choice but to develop their own capabilities. The people from developing countries are familiar with the labor-intensive approach and can provide the proper environment for inuovations in this direction. For example, in a developing country, it should be desirable to use manual wiring techniques for the production of switching equipment rather than sophisticated, automatic, computer-coutrolled wiring machines that require millions of dollars of investment. No doubt, manual wiring introduces error; however, the manual approach in this case provides a considerable number of jobs and does not need a large amount of foreign exchange for new equipment. The labor-intensive approach should not mean installation of old unreliable equipment so that more jobs can be created to repair it, nor should it mean going back in time to nature without regard for moderu technology. It means there has to be a proper balance of technology and human participation.

B. Capital Sensitivity

The third way to telecommunication development emphasizes capital sensitivity through the following two concepts: 1) The capital available for telecommunication development is limited and, as a result, must be used to benefit a large number of people. For example, if investment is available to add ten telephone lines in a small town, should it go to bureaucrats, rich, and the elite who can afford it or should it go to schools, hospitals, etc. in the form of public phones. In brief, with the available sources, how do you plan your programs to benefit everyone?

2) The large development programs, which are based on large-scale economy in terms of investment and returns, should be avoided. The production facility should also be based on the capital-sensitive, labor-intensive approach. For example, automatic machines to insert components would be desirable from the viewpoint of efficiency. But in developing countries, it would require additional capital, most probably in foreign currency, and replace several jobs. These approaches should be carefully evaluated.

C. Self-Reliance

The emphasis on self-reliance is extremely important. It fosters development from within. The local population realizes the potential needs and recognizes the spontaneous situation. However, for them to be useful, self-reliance has to be emphasized at the beginning of the program. They should participate in the planning, engineering, production, maintenance, and service aspects to be really productive.

Self-reliance and local participation should be emphasized at all levels. For example, there is no reason why public telephones should not work in a university town where postgraduate work in all engineering fields is offered and at the same time, hundreds of college graduates are unemployed. The university staff and student community should take it upon themselves to participate in a telephone maintenance program as a part of the graduate course. They should make sure that all phones in their own community are maintained properly. This requires cooperation from the telephoue admiuistration and a change in the present procedure. In a developing country, capital equipment is limited and should not be left idle or unoperated at the cost of capital required for the manpower needed.

Self-reliance does not mean a curb on all imports and isolated growth. Self-reliance means active local participation at all levels to be productive for local needs.

In brief, the third way to telecommunication development emphasizes new objectives and new guidelines which are third world oriented. It is recognized that the key to the third way development is technology. The appropriate technology would result in benefits for all at minimum cost. The technology center aimed at providing the technology required to implement the third way to telecommunication development is now discussed.

VI. TELECOMMUNICATION TECHNOLOGY CENTER

In order to implement the third way development program, it is suggested that an autonomous, nonprofit Telecommunication Technology Center be established for developing countries. The objective of this center would be to develop appropriate technologies for the telecommunication needs of developing countries. It would provide a mechanism for technical participation from all over the world that would include both developing and developed nations. The center would be responsible for coordinating communication developments in developing nations. It would be different from the International Telecommunication Union (ITU) or other existing organizations due to its emphasis on being a product-oriented technology center.

The implementation of the Technology Center would require considerable international understanding and cooperation. If telecommunication services in developing countries are viewed only as potential markets, the solutions are going to be undesirable. The telecommunication services have to be viewed as a fundamental social need of modern society that is trying to solve global problems. The needs of developing countries in the area of telecommunication have to be recognized and dealt with through collaboration. This collaboration cannot be just between banks and multinational corporations; it must be between governments and international institutions.

Five aspects of the Technology Center are briefly discussed here: 1) objectives, 2) organization, 3) activities, 4) location, and 5) finances.

A. Objectives

The objective of the Technology Center would be to provide telecommunication plans, programs, and products based on guidelines from the third way approach, for the developing countries. The center would make a clear distinction between science and technology and, as a result, would deal only with the application of science. The aspects of appropriate technology would be the emphasis of the center. It would be product oriented and provide product-oriented ideas, designs, and assistance.

The center would be responsible for international compatibility standards for all developing countries. It would try to develop a set of standard product lines suitable for application in a majority of the developing countries. It would emphasize technological leapfrogging and suggest new concepts compatible with state of the art technologies. The telecommunication center would also provide assistance in manufacturing technology.

B. Organization

An international organization similar in structure to INTELSAT, which requires government participation and not corporate participation, would be ideal for implementing this program.

It is recognized that the third way to telecommunication development emphasizes the third world elements. As a result, it is believed that the solutions have to come from within the developing community. The organization would rely heavily on staff from developing countries. It would also include scientists and engineers from developed nations working for a common goal.

A typical organization is suggested in which the central responsibility of the managing director would be shared by several directors in various technologies, such as systems, hardware, software, components, and manufacturing. For efficiency and control, a product-oriented organization is preferred. This results in a matrix structure with technological responsibility on one axis and specific product responsibility on the other.

C. Activities

The overall activities would include, beside technology monitoring, and technology participation, specific product development. It is believed that technology in the area of semiconductors is very complex and changes rapidly. As a result, it is desirable to borrow semiconductor technology by importing components such as IC's, microprocessors, memories, etc. Thus, the manufacturing activities would result in a simple assembly process. The activities would be divided into three major product lines: 1) terminal equipments, 2) carrier and signaling, and 3) switching.

The products would be designed to meet local needs. For example, due to heavy traffic generated in developing countries, it would be desirable to design nonblocking switching networks. These networks are not cost competitive using analog concepts; however, with digital concepts, nonblocking networks are practical at lower costs. It is recognized that skilled manpower is limited in the developing countries. As a result, a centralized maintenance system with remote access to a majority of the new facilities would be necessary.

Detailed cost analysis, based on developing country models, would be an important activity of the center. For example, when initial cost comparisons of a particular technology is made in developing countries, it is rarely emphasized that the high markups and overheads from industrialized nations are normally included in the price structure. A telecommunication system that is sold on an interuational market for $1000 probably, includes a $500 markup, $300 labor and overhead, and $200 components, half of which could be reduced through local substitution. As a result, the system, which is sold on an international market for $1000 might cost only $100 worth of foreign exchange if proper technology is available to assemble it locally.

As an initial activity, the center would survey the immediate needs of various developing countries and define system parameters for rural networks. This would include the definition of average system size, basic features, technology to be used, and various other data required to begin detailed design activities. It would also include comparison between various concepts, such as line concentrators, remote satellite switching, centralized maintenance, for a rural switching configuration. The objective would be the sharing of the production of standard telecommunications equipment by developing countries.

As mentioned earlier, one of the activities of the Technology Center would be to participate in international organizations to set up compatibility requirements for transmission, signaling, and switching. At present, the International Telegraph and Telephone Consultative Committee (CCITT) and International Radio Consultative Committee (CCIR) meetings to define standards are attended by the majority of the developing countries with at least one representative from a country as small as Fiji (0.5 million population) and as large as India (600 million population). These meetings are a foreign exchange drain on some of the small countries. The center would participate on behalf of developing conntries with the idea of relaxing some of the standards for rural applications.

The center would provide consulting services to telephone administrations in developing countries. The traditional role of multinational corporations as advisors to telephone planners in developing countries is now being changed by consultants from industrialized countries. More and more developing countries are hiring consultants to plan their networks. These consultants along with their sophisticated technology bring their own way of modernizing developing countries. They lack experience in the third world conditions and approaches. The center would provide the proper balance between technology and applications in the third world nations.

D. Location

The location for the center is a very crucial issue. Based on the excitement in telecommunication technology and advances in semiconductor industry, it appears that the U.S. would be a good choice. However, the program outlined in this paper emphasizes the contribution which has to come from the third world countries. Based on this third world element, it is necessary that the center be established in a developing nation.

TABLE I
DEGREES AWARDED IN INDIA

	1970	1973
Science		
B.S.	83,698	106,489
M.S.	12,686	16,149
Ph. D.	1,107	1,327
Engineering		
B.S.	19,316	14,342
M.S.	1,201	1,263
Ph. D.	98	110

There are two major criteria used to select the location: 1) availability of technical manpower and 2) finance. As mentioned earlier, the technical staff would consist of people from all over the world. However, the miscellaneous technical manpower needed for the center has to be available locally. At the same time, it is also assumed that a certain level of infrastructure for electronics technology and ancillary industries is available locally. Based strictly on the engineering manpower issue and the available infrastructure for electronics industries, India seems to be a good choice. India has about 4300 colleges affiliated to 103 universities. There is a total of 460 engineering institutions with 290 providing associate degrees and 160 providing graduate programs. The degrees awarded in science and technology in India for the years 1970 and 1973 [5] are shown in Table I. Because of their financial resources, any of the oil-exporting middle eastern countries would be a strong alternative.

E. Finances

In order to operate a facility of this magnitude, considerable financial resources are needed. These could come from the participating countries, their administrations, or other international agencies. Due to the difference in the cost of living in the developing countries, it is expected that the local operating expenses would be reasonable. It is estimated that a professional staff of 100 people with 200 support people would be required in the beginning. This would require an operating budget of about 5 million dollars per year.

VII. COMMUNITY TELEPHONE

The community telephone is an example of a product based on the third world model. As mentioned earlier, telephone planning in developing countries tries to satisfy a long list of waiting customers, thereby increasing telephone density. With the limited resources available, it is not possible to satisfy the ever increasing demand for private telephones. As a result, a community telephone, providing services to a small community through one telephone line, is suggested for both the urban and rural areas of developing countries. Every community would be provided with a "community phone" but members of that community would be denied private telephones. As a result, with only a minimum telephone density, a large proportion of the population can have access to the national telecommunication network.

There are two aspects of the developing countries which make the community telephone concept attractive: 1) the generally warm climate and 2) the life style of the people. Most of the developing countries have a warm climate and as a result, it would be convenient to operate an outside telephone. It could be answered either by an assigned individual paid by the community or by a member of the local youth organization. The life style of the people in developing countries is such that the telephone on a street would be a natural extension of street activities. In most of these countries, the normal life inside the house is almost the same as the life outside. People drink, eat, sleep, dress, and socialize out on the street. In fact, the street, with hundreds of clustered houses, is full of social activities at all times. In an environment of this type, one telephone per street seems an appropriate pattern for telecommunication growth.

The community telephone would not be just a public telephone. It would also have speaker phone capabilities for local conferences between the village communities, and will thus generate high traffic. Because of the high traffic, it would have considerable impact on the national network. Hughes [6] suggested that the coin required to operate community telephones could be identical in all developing countries. This would simplify system design and eliminate problems in areas where coins keep changing every few years. In order to provide a preliminary proposal for use in developing countries, various areas such as system design, implementation, maintenance, and network planning need to be investigated.

VIII. CONCLUSION

In conclusion, the telecommunication development in developing countries is based on the industrialized model that emphasizes imported technology and an increase in telephone density. An alternative approach to telecommunication development in developing countries is suggested. The third way to the telecommunication development emphasizes rural communication, accessibility, and reliability. In order to implement the third way development program, it is suggested that an autonomous, nonprofit Technology Center be established in a developing country. As an example, the concept of the community telephone is outlined.

It appears that the third way approach provides a wide range of alternatives which need to be explored. For any meaningful contribution, the real implications of this new concept need to be analyzed through further interdisciplinary research. Considerably more work needs to be done in this area before a concrete program, ready to be implemented, can be presented.

ACKNOWLEDGMENT

The author wishes to thank Dr. D. S. Desai for continuing encouragement and J. A. Ellis and Dr. P. N. Desai for reviewing the manuscript. The author wishes to acknowledge the members of India Forum, Chicago and the members of the

Center for Studying Developing Societies in New Delhi for many fruitful discussions.

REFERENCES

[1] H. Chasia, "Choice of technology for rural telecommunication in developing countries," this issue, pp. 732-736.
[2] B. B. Wellenius, "Some recurrent problems of telecommunications in developing countries," this issue, pp. 723-728.
[3] B. Prasada, "Some implications of telecommunication policies in developing countries," this issue, pp. 729-732.
[4] "Perfect telco studies U.S. industry," *Telephony*, p. 118, Jan. 7, 1974.
[5] "Educational stastics," Tech. Education Div. of Ministry of Education, Embassy of India, Washington, DC.
[6] T. F. Hughes, private communication.

★

Satyan G. Pitroda (M'67), for a photograph and biography see page 675 of this issue.

INTELSAT and the Developing World

IRVING GOLDSTEIN

***Abstract*—Adequate telecommunications facilities to meet both internal and external telecommunications requirements are important prerequisites for a country's development. The International Telecommunications Satellite Organization (INTELSAT) has been cognizant of this fact, and has endeavored to respond to the needs of the developing world in a variety of ways. This paper discusses why developing countries have turned to INTELSAT to meet their telecommunications requirements, how INTELSAT has responded to this need and fostered such usage, and what activities INTELSAT is contemplating for the future which are likely to continue and improve upon this trend.**

> As nations move from the patterns of traditional society toward the patterns of modern industrial society, spectacular developments take place in their communication. From one point of view, developments in communication are brought about by the economic, social, and political evolution which is part of the national growth. From another viewpoint, however, they are among the chief makers and movers of that evolution.[1]

I. INTRODUCTION

THE importance of adequate telecommunications facilities in both generating and facilitating the development process has long been recognized since communications play a variety of roles in a country's development. The extent to which the communications framework can meet these demands and the degree of quality it can bring to bear in playing these roles will depend, in large measure, on the type of telecommunications facilities selected and how such facilities are provided.

The International Telecommunications Satellite Organization (INTELSAT), established in 1964 under interim arrangements and continuing under definitive arrangements (which entered into force in 1973), is capable both of increasing and enhancing the roles played by communications in the development of countries. As early as the passage of the Communications Satellite Act in 1962, the United States Congress was cognizant of this fact when it declared it to be the policy of the United States:

> ... to establish, in conjunction and in cooperation with other countries, as expeditiously as practicable a commercial communications satellite system, as part of an improved global communications network, ... In effectuating this program, *care and attention will be directed toward providing such services to economically less developed countries and areas as well as those more highly developed, ...* .[2]

A similar principle was reflected in both the interim and the definitive arrangements for INTELSAT since an objective of the organization under both sets of agreements was to permit access by all peoples to the global satellite system.

Since the creation of INTELSAT in 1964, developing countries have made increasing use of the services provided by the organization, and have become increasingly aware of its serviceability in meeting national objectives with respect to both external and internal communications requirements. INTELSAT's original 19 members consisted exclusively of developed countries. However, by the time of entry into force of definitive arrangements, this pattern had clearly changed, has continued to do so through the present, and is reflected in INTELSAT's current membership encompassing 92 countries, the majority of which can be considered to be developing and whose usage, as shown in Fig. 1, currently reflects more than 30 percent of the total.

Why this has occurred, what INTELSAT has done to foster

Manuscript received December 18, 1975; revised February 18, 1976.

The author is with the Communications Satellite Corporation, Washington, DC 20024.

[1] W. Schramm, "Communication development and the development process," in *Communications and Political Development*, L. W. Pye, Ed. Princeton, NJ: Princeton Univ. Press, 1963, p. 30.

[2] Communications Satellite Act, 47 U.S.C. 701(a) and (b) (emphasis supplied).

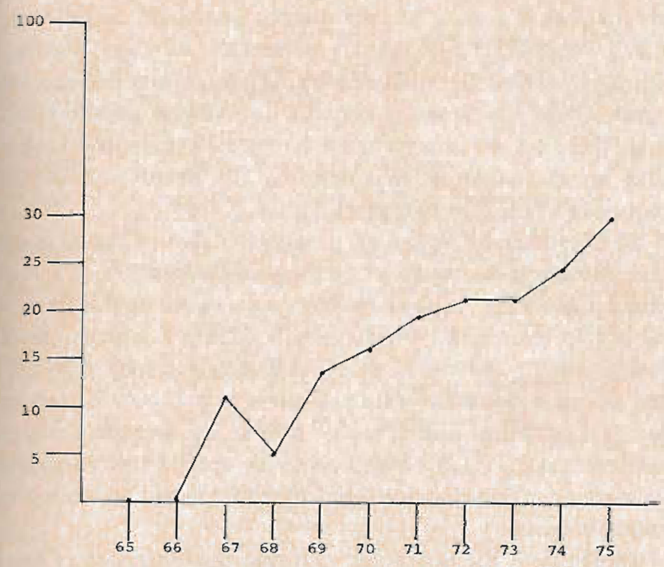


Fig. 1. Use of INTELSAT satellites by developing countries as a percent of total full-time utilization.

this development, and what INTELSAT may be expected to do in the future to enhance this trend are worthy of examination.

II. THE INTELSAT SYSTEM

Prior to the availability of satellite telecommunications, direct communications links between and among many countries, particularly those in developing areas, were complicated, circuitous, and sometimes even nonexistent. Countries which were neighbors, such as Argentina and Brazil, were frequently unable to communicate with each other, and the developing countries of Africa, Asia, and Latin America were in many instances without reliable telecommunications facilities, depending instead on the vagaries of HF radio. Now, given INTELSAT's impressive record of achievement, all a country needs to do is to invest in the construction of one earth station, and it will have direct reliable communications to virtually any part of the world.

A. Scope of Activities

INTELSAT currently provides a variety of public telecommunications services. Its prime objective is the provision on a commerical basis of the space segment for international public telecommunications services of high quality and reliability to be available on a nondiscriminatory basis to all areas of the world. Certain domestic public telecommunications services between areas separated by the high seas, or by natural barriers preventing the establishment of terrestrial facilities (if approval is obtained in advance from INTELSAT's Meeting of Signatories in the case of the latter), are to be treated on the same basis as international public services. Other domestic public telecommunications services may be provided on the INTELSAT space segment on a nondiscriminatory basis to the extent that INTELSAT's ability to achieve its primary objective is not impaired. In addition, INTELSAT may provide, on request and under appropriate terms and conditions, satellites separate from the INTELSAT space segment for domestic and international public telecommunications services and domestic and international specialized telecommunications services, pursuant to appropriate technical, operational, and financial terms and conditions as set forth in the Agreements.

B. The INTELSAT Space Segment

To meet increasing requirements for and to ensure continuing availability of telecommunications facilities, INTELSAT since 1964 has launched and put into operation more than four generations of satellites, each generation more powerful than the one preceding it. The INTELSAT I or "Early Bird" satellite, launched in April 1965 and placed over the Atlantic Ocean area, had a capacity of 240 voice quality circuits, or one television channel, and an expected life of 18 months.

As of January 1976, INTELSAT had in operation four satellites (two in the Atlantic and one each in the Indian Ocean Region and the Pacific Ocean Region, and three additional satellites as spares in orbit, one for each ocean region). Service in the Atlantic Ocean Region is provided by one INTELSAT IV-A and one INTELSAT IV satellite with an INTELSAT IV-A as backup. Service and backup in the Pacific and Indian Ocean Regions are provided by INTELSAT IV satellites. Each INTELSAT IV satellite has 12 transponders and is capable of providing an average of 4000 circuits or 12 television channels or combinations thereof. Each INTELSAT IV-A satellite with 20 transponders has approximately double the usable capabity of INTELSAT IV; four more INTELSAT IV-A satellites are scheduled to be launched to augment the INTELSAT IV system during the next few years.

INTELSAT presently is considering and planning for the next generation of satellites the INTELSAT V series which is expected to commence operation in the 1979/1980 time frame and for which the contract is expected to be concluded before the end of 1976. The INTELSAT V design upon which the RFP (request for proposal) is based incorporates the use of the 14/11 GHz frequency band and uses extensive frequency reuse by dual polarization and beam separation to provide increased capacity in the 6/4 GHz frequency spectrum. When used as the Atlantic Ocean Region Primary Satellite, it is estimated that this satellite will be capable of providing for 24 000 assigned telephony channels, as well as providing for SPADE and occasional use services, including TV.

The ground segment, the earth stations, are under the control of each Signatory, although INTELSAT is responsible for establishing standards to which earth stations are expected to conform before they will be permitted access to the system.

III. REQUIREMENTS OF THE DEVELOPING WORLD

As countries' communications requirements have grown, initial efforts both with respect to satellite communications and other media appear to have been focused on linking a country's capital city with other major capitals throughout the world. Once international telecommunications needs were being met satisfactorily, a country's focus turned inward, and in many cases it readily became apparent that the biggest communications problems might lie with the shortest distances to be covered. Thus, countries have turned first to INTELSAT to meet international demands, and only recently, as these requirements have been met, have countries turned more and more to INTELSAT to satisfy domestic needs.

Satellite telecommunications have a number of unique features which make them more acceptable to developing countries in particular, than submarine cables or HF radio to meet international requirements. These include

1) simultaneous use by several earth stations;

2) high-quality, reliable telecommunications;

3) introduction of services not available previously on an intercontinental basis, such as international television, data and computer exchanges, and aircraft and seacraft position location;

4) high levels of cost savings and economic benefits; and

5) reduction of the gap between nations in knowledge and development of technical capability.[3]

These characteristics have indeed been reflected in the following milestones in INTELSAT's 11-year history.

1) As of January 1976, 131 operational antennas (both standard and nonstandard) were providing service at 104 earth stations among 71 countries.

2) Developing countries, in particular, have joined INTELSAT, invested in and constructed earth stations, and accessed INTELSAT satellites. More than two-thirds of INTELSAT's 92 members are countries located in Africa and the Middle East (33) , Asia (13), and Latin America and the Caribbean (18). More than two-thirds of these currently use the INTELSAT system.

3) Live intercontinental television broadcasts for news, sports and entertainment are a regular occurrence.

4) INTELSAT utilization charges have decreased annually, from \$32 000 per annum in 1965 to \$8280 per annum as of January 1, 1976.

While both the interim and definitive arrangements legally permitted provision of a variety of service offerings, including provision of domestic public telecommunications, it has not been until recently, 1972, that Signatories have explicitly sought such services. Since that time, such requests have come with increasing frequency, and for this purpose, ten Signatories have sought and/or completed long-term allotment agreements for such use of INTELSAT space segment capacity. These Signatories and the nature of their allotment agreements are summarized in Table I.

In response to these requests, INTELSAT has evolved a policy whereby a developing country may come to INTELSAT and have available a variety of alternatives from which to choose to meet their requirements.

1) Allotment Capacity: A developing country may request lease of one or more transponders, one-half of a transponder, or one-quarter of a transponder in an INTELSAT IV satellite, pursuant to a decision by INTELSAT's governing body, the Board of Governors. Such requests can be for the purpose of meeting domestic requirements between areas separated by the high seas (e.g., U.S. mainland to Hawaii, and Malaysia for inter-island communications), between areas separated by natural barriers such as mountains, desert, or jungle (e.g., Brazil, Algeria), or for ordinary domestic needs (e.g., Nigeria). The time period for such allotments has ordinarily been for approximately a two-year period or a five-year period. However, there are no firm constraints regarding time period other than an expression of reluctance by the Board to entertain requests for less than two years.

2) Terms and Conditions: Long-term allotments of space segment capacity may be requested on a preemptible or a nonpreemptible basis. Capacity requested on a preemptible basis is subject to removal if operationally necessary in order to meet nonpreemptible service. Capacity which is not subject to preemption has the same status in terms of provision of service as that serving international public telecommunications requirements. Capacity leased on a preemptible basis is subject to more favorable charging terms than that leased on a nonpreemptible basis.

In addition, the Board has approved the utilization of nonstandard earth stations (i.e., earth stations with a G/T of less than 40.7°/K) in connection with such transponder leases where requested since the nonstandard stations would be operating only with each other and not with the rest of the INTELSAT system. (Thus far, Algeria, Brazil, Malaysia, and Nigeria have sought and been given approval to use nonstandard earth stations in connection with their leases.)

3) Charges: Upon receipt of the first request for bulk lease of space segment capacity by Brazil under the interim arrangements, INTELSAT's governing body under those arrangements, the Interim Communications Satellite Committee (ICSC) decided that the capacity would be charged for on the basis of 360 units per annum for full-time use of a global beam transponder, 360 units having been determined to be the average revenue-producing capacity of an INTELSAT IV global beam transponder. Hence, charges for long-term leases on a nonpreemptible basis are based on this 360-unit charge.

Algeria was the first Signatory to request bulk lease of a transponder on a preemptible basis in order to obtain a reduced rate. It proposed a flat rate of U.S. \$1 million per annum, with the intention that this would yield over the whole period of the contract an amount equivalent to about half the 360-unit rate established as the fully allocated cost for nonpreemptible service using an operational global beam transponder. INTELSAT accepted this proposal, and it became a precedent for determining subsequent charges for long-term preemptible allotments. Thus, charges for preemptible allotments for half of a transponder are U.S. \$500 000 and \$250 000 per annum, respectively. Brazil is utilizing its transponder for communications among earth stations separated by jungle. Norway's leasing of half of a transponder is providing communications to oil rigs in the North Sea.

Algeria was faced with the problem of establishing good and reliable communications between the main population centers in the Sahara and their administrative centers, and from there with northern Algeria and the rest of the world. In addition, these areas were to be provided with television for information and educational purposes. Living conditions were harsh, the towns were isolated, and the distances to be covered were sizable.

[3] See R. R. Colino, "International satellite telecommunications and developing countries," *J. Law and Economic Develop.*, vol. III, no. 1, Spring 1968.

TABLE I
LONG-TERM ALLOTMENT AGREEMENT FOR INTELSAT SATELLITE TRANSPONDERS

Allottee	Allotment	Initial Period	Charge	Intended Use
Signed Contracts				
Brazil	INTELSAT IV global beam transponder in Atlantic major path satellite.	30 months	Regular charge as for 360 units	Domestic telephony and television
Algeria	INTELSAT IV global beam transponder (or equivalent) in spare capacity in an Atlantic or Indian Ocean satellite subject to preemption by INTELSAT, if operationally necessary.	5 years	$1,000,000 per annum	Domestic telephony, telegraphy and television
Malaysia	INTELSAT IV global beam transponder (or equivalent) in spare capacity in an Indian Ocean or Pacific Ocean satellite, subject to preemption by INTELSAT if operationally necessary.	5 years	$1,000,000 per annum	Domestic telephony and television
Norway	One-half of INTELSAT global beam transponder (or equivalent) in spare capacity in an Indian Ocean or Pacific Ocean satellite, snbject to preemption by INTELSAT if operationally necessary.	5 years	$500,000 per annum	Domestic telephony, telegraphy and data services
United States	One global beam transponder (or equivalent) in the Pacific Ocean.	Initially 21 months	as for 360 units	Domestic telephony, telegraphy and television between Mainland and Hawaii
Prospective Agreements				
Zaire	INTELSAT IV global beam transponder (or equivalent) in spare capacity in an Atlantic or Indian Ocean satellite, subject to preemption by INTELSAT if operationally necessary.	5 years	$1,000,000 per annum	Domestic telephony and television
Nigeria	The allotment of spare capacity equivalent to two INTELSAT IV transponders in an Atlantic or Indian Ocean region satellite, subject to preemption.	5 years per transponder	$1,000,000 per annum	Domestic television distribution and message transmission
France	Allotment of spare capacity equivalent to one-half of an INTELSAT global beam transponder on a preemptible basis.	5 years	$500,000 per annum	Domestic services between France and St. Denis de la Rennion
Colombia	The allotment, in terms of capacity for preemptible leases for domestic public telecommunicatinns services equivalent to 1/4 of an INTELSAT IV global beam transponder with terms and conditions similar to the Norwegian allotment.	5 years	$250,000 per annum	
Spain	Allotment of one-half of a global transponder on an Atlantic Ocean Satellite on a non-preemptible for domestic public telecommunications.	1 year minimum	Regular space segment charge as for 180 units	Domestic services between Spain and the Canary Islands

The cost of attempting to establish a microwave system was estimated to be approximately U.S. $62 000 000. The reliability of any such system was highly questionable given the climatic and topographical conditions in which the system would have to function. In addition, in terms of initial and maintenance costs, lead time, and flexibility, the use of satellites was deemed far superior. For example, the total cost of the satellite network was estimated to be approximately U.S. $7 800 000 (an average of $550 000 for each of the 14 earth stations planned). Implementation of a microwave system was estimated to require more than five years, while that for construction of 14 earth stations less than two years.

Algeria first apprised INTELSAT of its needs in July 1973. INTELSAT's Board of Governors and the Board's technical and financial advisory committees reviewed Algeria's request, and in October 1973, the Board authorized the requested allotment and negotiation of an appropriate contract. In March 1974, Algeria requested that this prospective allotment be considered on the same basis as international public telecommunications services since it was of the special type described in the Agreement, and they requested the Board to so advise the Meeting of Signatories. In April 1974, the Meeting of Signatories gave the necessary approval. The contract was concluded and approved by the Board in September 1974. The Algerian domestic service commenced operation on February 27, 1975.

A. Technical and Operational Benefits

To ensure the availability of adequate facilities for international public telecommunications services of high quality and reliability and those domestic public telecommunications services treated on the same basis, INTELSAT continually assesses future requirements, plans for expected increases in demand, and evaluates and, where appropriate, introduces new technologies into the system.

One such technological development which can beuefit smaller users is SPADE, an acronym for single channel per carrier pulse-code modulation multiple-access demand-assigned equipment. SPADE permits use of the satellite system on an occasional, as-needed basis in lieu of a full-time allotment for whatever number of channels required. Hence, with SPADE, a country can communicate with another country for the time required for the particular communication without having to maintain a full-time cuircuit at a cost their communications traffic would not justify. The charge established by INTELSAT for this service is U.S. 10 cents per minute. As of November 1975, SPADE service billable time averaged 26 467 minutes per day, and 188 demand-assigned channel units were activated at 19 SPADE terminals around the world.

The coverage areas of transponders leased which will be available in the near future within the INTELSAT system will range from global, i.e., approximately one-third of the earth's surface, to hemispheric, i.e., approximately one-third of the coverage of a global beam and generally pointed toward large land masses, to spot, which is a very narrow pencil-shaped beam directed toward a precise locatiou on the earth's surface. The number of leased services that can be accommodated in a transponder is primarily dependent on the type of transponder leased and the size and number of the earth stations accessing the transponder. It is conceivable that multiple requests for leased services could be provided for in a spot or hemispheric transponder if there existed a commonality of need within a limited geographical area. All leased services to date have been provided through global transponders.

The ability of a system to support leased services is directly related to an earth station's G/T. As this figure of performance decreases (with a corresponding decrease in the size of an earth station), the number of leased services that can be accommodated through a transponder decreases, as illustrated in the representative table below.

INTELSAT IV Global Transponder Service Capacity

Type of Earth Station	Earth Station G/T in °/K	Channel Capacity for FDMA/FM (Single Carrier)	Channel Capacity for FDMA/FM (Multicarrier)
Standard	40.7	972	500
Nonstandard	31.7	540	240
Nonstandard	22.7	72	48

These characteristics of INTELSAT's approach and of the INTELSAT system are especially conducive to the accommodation of either international public telecommunications requirements or bulk lease domestic public telecommunications services. A developing country is assured of viable communications facilities in sufficient quantities to meet both external and internal communications needs for whatever time period deemed appropriate. Also, a developing country receives the benefits of a sophisticated technology which it would be incapable of establishing and supporting alone.

Developing countries oftentimes are situated in those areas of the world where geography tends to create adverse conditions, causing and/or contributing to the developing country's inability to progress economically and socially. Satellite telecommunications neutralize many such physical barriers, and INTELSAT is accutely aware of this fact, as reflected by INTELSAT equating certain types of domestic public communications services with international public telecommunications services.

B. Financial

Any country, whether or not a member of INTELSAT, may utilize the INTELSAT system. Countries which are nonmember users include Bahrain, Bangladesh, Mauritius, People's Republic of China, and the U.S.S.R. Pursuant to specific provision in the Agreement, all users of the INTELSAT space segment pay the same utilization charges, and the charge for each type of utilization is the same for all users for that type of utilization; thus, there is no charging penalty to nonmember users.

If a country does become a member, it automatically becomes an owner to the extent of its investment share, and certain financial benefits and obligations attach which do not apply to nonmember users. Each member has an investment share corresponding to the percentage of its utilization of the INTELSAT space segment to that of all members. If the member does not yet utilize the system, it automatically is given a minimum investment share of 0.05 percent. Investment shares are adjusted annually to take into account changes in utilization. In accordance with its investment share, each member contributes to the capital requirements of INTELSAT and is entitled to receive compensation for the use of capital.

As previously noted, INTELSAT space segment charges have continuously decreased as use of the system has expanded, and this downward trend is expected to continue. In addition, if a country is willing to conclude a lease arrangement subject to preemption, it can obtain such services on even more favorable financial conditions. As a consequence, any user of the INTELSAT system is receiving quality service at a minimal cost. While this is beneficial to any country, it appears to be particularly advantageous to developing countries which usually have scarce capital and monetary resources which must be allocated among numerous pressing needs. Thus, by using the INTELSAT system, not only is a developing country saved the additional investment commitment incumbent upon meeting all communications requirements independently, but also, the developing country is obtaining maximum worth from its financial participation, and at a risk far lower than would be the case if a separate system were established for just one such country's requirements.

A developing country is able to minimize financial risk-taking by pursuing the INTELSAT approach. The risks associated with such a venture are spread among a large number of participants, and only to the extent of their usage of the system. In addition, even if the domestic leased service is preemptible, many of the countries in developing areas are able to "see" satellites in two of the three ocean regions. Hence, even if the leased service may be interrupted (preempted) in one ocean region, the leasing Signatory could be capable of restoring it in the other ocean region merely by repointing its earth station.

C. Political

As the number of developing countries becoming INTELSAT members and utilizing the INTELSAT system has increased, their participation in the decision-making and operation of the organization has also grown. INTELSAT has four major organs.

1) An Assembly of Parties (the governments) whose function is the consideration of those aspects of INTELSAT which are primarily of interest to the Parties as sovereign states.

2) A Meeting of Signatories (the telecommunications entities public or private, designated by the Parties) which considers technical, operational, and financial questions.

3) A Board of Governors with prime responsibility for the design, development construction, establishment, operation, and maintenance of the INTELSAT space segment.

4) An executive organ responsible to the Board of Governors, headed until December 31, 1976 by a Secretary General and thereafter by a Director General.

INTELSAT's structure under the definitive arrangements, as outlined above, reflects a significant change from the interim arrangements in that the voice of small users, the majority of which are developing countries, has been increased by the creation of two bodies of the entire membership, the Assembly of Parties and the Meeting of Signatories. Important steps were also taken with respect to the Board of Governors.

The Board of Governors is composed of any Signatory or group of Signatories whose investment share either singly or combined meets a minimum investment share determined annually by the Meeting of Signatories pursuant to guidelines set forth in the Agreement. In addition, in recognition of the large number of small users and developing countries, the definitive arrangements provide for representation on the Board of up to five groups composed of five or more Signatories from each of the five ITU regions, regardless of their investment shares.

The five ITU regions are Region A (the Americas), Region B (Western Europe), Region C (Eastern Europe and Northern Asia), Region D (Africa), and Region E (Asia and Australasia). Presently, there are four Governors on the Board representing regional groups, two from Africa and one each from the Caribbean and the Scandinavian countries. The Agreement provides that the number of Governors under this category is not to exceed two from any region or five from all such regions.

However, regional representation notwithstanding, many developing countries have been able to obtain representation on the Board by meeting the minimum investment share either singly or by combining. Presently, 25 Governors representing 73 of INTELSAT's 92 Signatories compose the Board. Each Governor has a voting participation equal to the investment share of the Signatory or Signatories he represents for that position reflecting use to meet international public telecommunications requirements and certain types of domestic public telecommunications needs as specified in the Agreement. Thus, a developing country utilizing INTELSAT to meet certain of its domestic public telecommunications requirements not only receives the technical, operational, and financial advantages described above, but also can have its investment role in the organization's decision-making process enhanced proportionately.

IV. NEW DEVELOPMENTS

INTELSAT continuously has under review ways in which the INTELSAT network can evolve. To this end, it studies on a continuing basis, *inter alia,* the implications of new technologies, new transmission methods and the new systems relevant to both space and earth segments which the INTELSAT system and its users might employ, and the implications of the use of nonstandard earth stations in the INTELSAT system. Nonstandard earth stations have had, and are expected to continue to have, two major on-going uses within the INTELSAT system: in connection with domestic transponder leases, with no financial rate adjustment factor applied, leaving it to the leasing country to define the optimum tradeoffs vis-à-vis the use of nonstandard stations; and in connection with normal commercial use in the global system, subject to appropriate financial rate adjustment factors as determined in each case. The use of nonstandard earth stations in the INTELSAT system and in connection with domestic transponder leases does have certain advantages, particularly for developing countries.

Since the early years of its operation, INTELSAT has considered and approved access to the INTELSAT space segment by various types of nonstandard stations on a case-by-case basis. Depending on the extent to which the nonstandard station deviated from the criteria established for standard stations, varying financial rate adjustment factors were established reflecting the larger amount of satellite capacity required. Nonstandard stations have been and are expected to continue to be utilized for the following purposes.

1) Permanent use for regular commercial service in connection with leased facilities or access to the global system (e.g., for access to major path satellites, remote areas, small traffic streams, television).

2) Temporary use for commercial services for a limited period of time (e.g., disaster relief, restoration of other communications facilities, coverage of special events).

3) Tests and demonstrations frequently using satellite capacity at no charge.

Because of INTELSAT's planning premises and objectives, the organization finds itself with differing amounts of spare space segment capacity available in certain regions at certain times. Hence, INTELSAT is in a position to consider the development of appropriate guidelines for access to the system by small stations for a variety of purposes, e.g., normal full-time service on a controlled basis, full-time service of a particular nature, service designed to utilize spare capacity.

For certain countries, in particular developing countries, and/or for certain types of service, it may be more economical to build and operate a small earth station. Cost comparisons between small and standard earth stations studied by INTELSAT indicate generally that, where the requirements are unlikely to exceed 24 channels over the expected system life, a small earth station with a G/T in the region of 31.7 dB/K and with the present rate adjustment factor of 2.5 times the normal utilization charge can provide service at lower total cost than a standard earth station. Low density traffic streams which are presently carried by other means could possibly be carried more economically by satellite using small earth terminals. Such a change in the mode of transmission would not only benefit the interconnectivity of the network, but could also upgrade the quality of transmission. Development and commercial availability of new modulation techniques and equipment which make more efficient use of satellite power/bandwidth resource or which could operate with lower power flux density would also encourage the use of small earth terminals for specialized data and message applications. Similarly, commercial availability of a limited range of standardized antennas, at economic prices, could substantially reduce the investment costs of small terminals. This, coupled with possible unattended operation and programmed maintenance, could make the small terminals more attractive, even allowing for the rate adjustment factors which might apply.

Cognizant of all these factors and after extensive studies, INTELSAT is presently considering the establishment of a second standard for earth stations operating within the INTELSAT global system with a minimum G/T of 31.7 dB/K in the 4 GHz band using SCPC since this size of nonstandard earth station appears optimum given the various factors which must be juxtaposed. The extent to which any financial rate adjustment factors or other operating constraints would need to be applied has not yet been determined. Nonstandard earth stations with a G/T of less than 31.7 dB/K or those using FDM/FM would still be considered for access to the space segment on a case-by-case basis, as in the past.

V. CONCLUSIONS

The past ten years has witnessed a mushrooming of demand for and interest in satellite communications, both internationally and domestically. The advantages of multipoint accessibility, including remote areas; TV capability, in additon to telephony, telegraphy, telex, and data transmission; high capacity; and coverage of vast distances with little maintenance, added to the proven reliability of satellite communications have presented telecommunications planners with what seems to be almost an ideal system. The attraction of satellite communications is heightened within developing regions by the desire for an independent communications capability and the absence of a sophisticated telecommunications infrastructure as exists in developed countries.

INTELSAT both now and in the future can offer valuable services to developing countries as they seek to maximize these possibilities for internal and external telecommunications requirements at minimal cost. This fact has long been recognized by developing countries, as attested to by their growth among the ranks of INTELSAT members and users.

Not only have developing countries been cognizant of benefits accruing to them by virtue of INTELSAT use, but also INTELSAT has been aware of its value and its obligations in meeting such requirements. This awareness is reflected in INTELSAT's structure, its decision-making apparatus, its scope of service offerings, and its development planning.

ACKNOWLEDGMENT

The author wishes to express his deep appreciation to S. B. Badinelli of the International Affairs Division of the Communications Satellite Corporation, who assisted in the preparation of this paper.

★

Irving Goldstein was born in Catskill, NY. He received the B.A. degree in political science and international relations from Queens College of the City Univeristy of New York, Flushing, NY, in 1960 and the J.D. degree from the New York University School of Law, New York, NY, in 1963.

Following three years with the Federal Communications Commission, he joined the Communications Satellite Corporation (COMSAT) Office of General Counsel, Washington, DC, in 1966. In February 1972 he was named Director of COMSAT's European Office, with responsibility for corporate interests and activities in Europe, Africa, and the Middle East. In July 1974 he was appointed Director of International Affairs, a position he presently holds. He also serves as Alternate U.S. Governor to the INTELSAT Board of Governors and U.S. Representative to the Board of Governors Advisory Committee on Planning.

Mr. Goldstein is a member of the Bar of the District of Columbia and of the State of New York.

Pan-African Telecommunication Network: A Case for Telecommunications in the Development of Africa

PHILIP O. OKUNDI

Abstract—Some of the special problems and constraints associated with African Continental Telecommunications are reviewed. A description of plans to establish a continental terrestrial telecommunication network—now called the Pan-African Telecommunication (PANAFTEL)—network is given together with traffic predictions. Future development of such a network in a rapidly expanding traffic environment is surveyed taking into account the complementary role which a domestic satellite communication system would play.

INTRODUCTION

All studies of the economic situation in Africa undertaken by international agencies emphasize the urgent need for integration of the African economies [1] to accelerate the rate of economic growth for the purpose of not only maintaining, but also raising the standard of living of the African people. One of the essential prerequisites for economic integration is the development of a sound infrastructure in the telecommunications sector since establishment of a modern, reliable, and rapidly expanding telecommunication network contributes considerably to the promotion of a variety of activities of economic expansion.

The African continent consists of some 54 countries encompassing some formidable geographical obstacles such as the great deserts of the Sahara and Kalahari, the thick equatorial forest along the Zaire river, and the Great Rift Valley stretching the length of the continent. These physical factors have dictated the population distribution which predominates along the coastal regions and along the fertile river basins isolating the community into eastern, southern, central, western, and northern zones. Apart from geographical barriers, political and language groupings exist which further complicate the development of the domestic telecommunication network.

The historical development of the African telecommunication network has been dominated by commercial and administrative relatious with Europe and, as a consequence, a large amount of domestic traffic is still routed through Europe which results in very high and completely unrelated telecommunications tariff structures [2]. In addition, the emergence of former colonial territories as sovereign independent states, each concentrating on the development of its own network, has precluded the overall improvement of inter-African communication. Thus when viewed in comparison with other countries, African telecommunications development has not kept pace with its general economic development.

Manuscript received January 19, 1976. This paper was presented at the World Telecommunications Forum, Geneva, Switzerland, October 6–8, 1975.

The author is with the East African Posts and Telecommunications Corporation, Nairobi, Kenya.

It is within this rather complex framework that the Organization for African Unity recognized the urgent need to develop an inter-African telecommunications network while preserving the commercial and cultural links with Europe and other continents, thereby laying a basis for the Pan-African Telecommunications (PANAFTEL) Network.

GENERAL SITUATION OF THE AFRICAN TELECOMMUNICATION NETWORK

Most of the African national telecommunication networks are neither as developed nor as profitable as they should be, given the overall economic situation in these countries. The world telecommunication statistics for 1971 reveal that Africa has the lowest telephone density in the world, equalling 1.0 telephone instruments per 100 inhabitants (the next lowest is Asia with 1.8, while the world average is 7.8). When only independent African countries are considered the telephone density is considerably reduced to 0.57 telephones per 100 inhabitants.

Furthermore, analysis of amount of resources of the economy that is devoted to telecommunications over a given period [i.e., evaluating the ratio of investment in telecommunications to the gross domestic product (GDP)] indicates that this ratio did not exceed 4 percent in Africa during 1962–1968, whereas in most of the advanced countries, this ratio ranged from 4 to 9 percent during 1954 and as high as 12 percent in Japan in 1964 [1].

The long-distance telephone networks still consist of overhead lines equipped with low-capacity carriers or HF radio in most African countries, although some microwave radio relay links have recently been installed.

International links were, in general, installed and run by overseas companies, and these comprise HF radio for interstate communications; a considerable number of communication satellite earth stations operating within the INTELSAT global network have recently been installed. This latter communication medium has grown rapidly over the past few years but only insofar as points (capital cities in Africa) to other globally distant points through the INTELSAT global system are concerned. Interurban and inter-African telecommunication links are still much underdeveloped.

There is a rapid urbanization of the African population (the rate of population increase in towns is around 5 percent compared with about 2.4 percent for overall population increase) which is expected to result in a rapid increase in trunk telephone traffic with which the existing networks will be unable to cope. Delays of several hours—or days, when there is a breakdown—in the establishment of a trunk call will

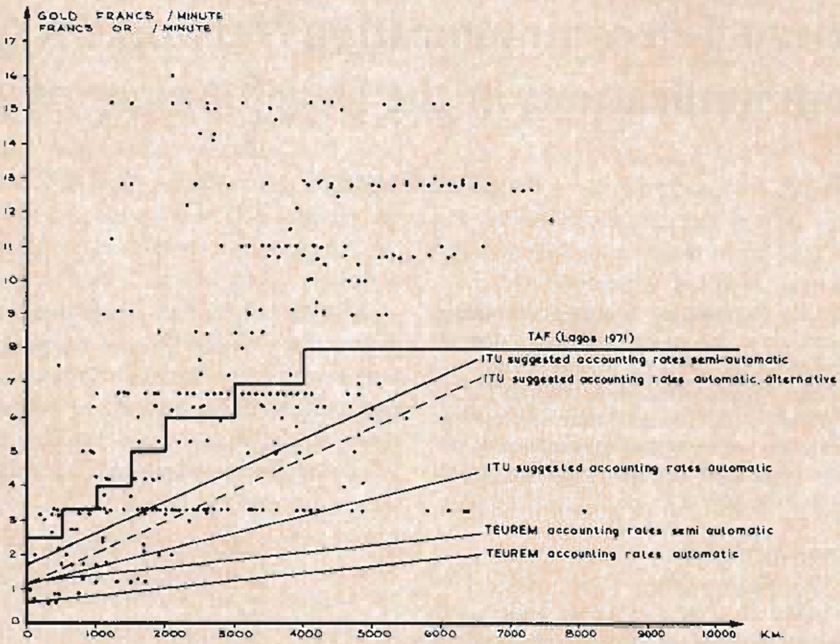


Fig. 1. Actual and estimated tariffs in Africa for telephone communication (as a function of the distance between international switching centers).

occur (this is, in fact, the case at the present time) as a consequence.

Wide differences in tariffs are in existence for both interstate and international telephone calls between the various operating organizations. The ITU's Tariff Study Group for Africa (TAF) has studied these tariff inhomogeneities and has found that telecommunications tariff structures in Africa are completely unrelated between the various operating administrations; and tariff relation to distance in Africa is nonexistent and therefore, no conclusions of a tariff relationship to distance can be drawn [2]. These deductions are explicitly explained by Fig. 1 where it is evident that whereas several administrations would have to raise their tariff levels, several would also have to lower their tariff levels in adopting a rational tariff structure for the continent. Consequently, there would clearly be considerable advantage from standardization once a homogeneous network is established.

RECOGNITION OF A PAN-AFRICAN TELECOMMUNICATIONS NETWORK

As a consequence of the above general historical survey of African telecommunications, the emergent African nations were quick to realize the following.

1) Telecommunications development in a country is vital in its total economic and social progress.

2) Telecommunications is a vital tool in the hands of governments in exercising their indispensible functions of control and administration at the national level, as well as enabling them to participate more fully in the life of the world community of nations.

It was necessary to take the following facts into consideration.

1) Most of the African countries do not, as yet, possess even the minimum telecommunication facilities necessary for government to exercise satisfactorily the basic functions in matters of administration in all parts of the territory.

2) In too many cases telecommunication traffic between African countries had to be routed through fairly remote non-African countries, even in cases where the African countries shared a common border.

3) Available international telecommunication links were acutely inadequate both in quantity and performance standards.

4) Because of the geography and demography of the continent, a good telecommunications link could act as a life line to a community, making its existence highly precious.

These considerations made the establishment of an efficient and up-to-date telecommunications network a first priority in accelerating the overall socioeconomic development of the continent. Indeed, all of the difficulties so far discussed in this paper are well considered by the new African countries and they are firmly committed to eliminating their effects.

The concept of the PANAFTEL network had been tossing in the minds of some of the leaders of the new African states, but it was not until 1962 when ITU organized a conference of African Postal and Telecommunication Administrations at Dakar, Senegal, that the first international plan for the development of an African telecommunication network was outlined. The conceptualization, planning, and implementation of an integrated telecommunications network to serve the vast African continent is surely a vast undertaking and must allow for realization over a period of years.

In late 1968, the ITU, as the executing agency under the United Nations Development Program (UNDP) began detailed preinvestment surveys in Africa of the international telecommunication requirements for the purpose of producing suggestions for the future plans of an integrated African international network for telephone, telex, telegraph, and television communication. In these preinvestment survey studies, the consultants examined all possible transmission media, i.e., open-wire lines, coaxial cables, submarine cables, radio relay systems as well as regional satellite systems and concluded that the most appropriate system for the immediate needs of Africa is a combination of coaxial cables and radio relay sustems. This conclusion was justified by the fact that PANAFTEL would not only provide connections between countries but would also provide communications between the major national centers, thus providing a medium for developing national networks at the same time. Accordingly, the PANAFTEL preinvestment survey is based upon these transmission media. A total of some 30 African countries are now involved in these surveys and studies which have been conducted by the ITU experts and international consultants under contract with the ITU.

The first output of the preinvestment surveys was discussed at the Meeting on the Implementation of the Pan-African Telecommunication Network held in Addis Ababa, Ethiopia, Oct. 30-Nov. 10, 1972 [2]. As these studies had not been completed in the West African region, a meeting was held in Lome, Togo, Apr. 17-19, 1973 [3] at which full discussion on the West African preinvestment survey output on their part of the network was completed.

At the Addis Ababa meeting, the links comprising the network were defined. The investment required to finance the network which is defined as entailing over 20 000 km of international transmission links accross the continent and 18 international switching centers, was estimated to be of the order of 100 million U.S. dollars in foreign exchange expenditure. Most of the transmission links in this network will consist of medium- to high-capacity microwave radio relay systems.

TRAFFIC CONSIDERATIONS

Two major traffic studies conducted by the ITU are available for the African continent. The first is a fairly detailed general plan for the development of the regional network [4] covering the period 1970-1978 for telephone, telegraph, and telex services. The second one is in connection with the PANAFTEL network [2] and covers the period 1975-1990 which shows a considerable increase over the previous study for the whole continent. Traffic forecasting for the African continent is very difficult owing to lack of reliable base traffic information. Consequently, the actual traffic requirements are normally very much uuderestimated by as much as 50 percent or more.

Viability of a telecommunication link is principally a function of the level of traffic desired over it. Because of this, and the inaccurate previous continental traffic forecasts, and the fact that there is cousiderable evidence of latent regional traffic, the ITU had to in effect, cause most of the PANAFTEL network to be viable. Thus after consultants had met with the ITU at a coordination working meeting to adopt common approaches to traffic estimation and circuit calculations for the whole region, the ITU applied an input jump of 50 percent to 1975 telephone traffic forecasts. A yearly

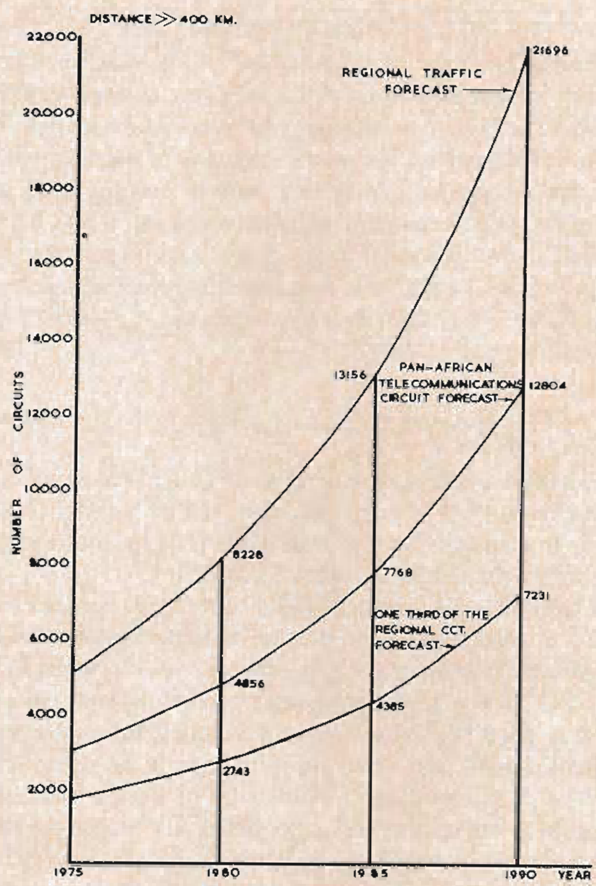


Fig. 2. Traffic projections for pan-African telecommunications network and estimated regional traffic.

increase of 20 percent was thus allowed for up to 1980, and thereafter, a 15 percent yearly increase.

Predicted telephony circuit forecasts for the PANAFTEL network, as well as the corresponding total regional network based on the above studies, is shown in Fig. 2.

The requirements for television and sound broadcasting are much more difficult to formulate but most of the PANAFTEL links are planned for 1 + 1 or 1 + 2 protected medium- to high-capacity telephony bearers, thus enabling the use of television and associated sound broadcasting on a part- or full-time basis.

In the East African sector, however, duplicated microwave radio relay (1 + 1) paths are planned and television will be transmitted on the protection channel similar to the existing backbone microwave system. In the event of main telephone channel failure, the protection channel will take on telephone traffic. Furthermore, the PANAFTEL link, like the existing backbone microwave system, is planned to transmit data on 12 of the available 960 telephony channels.

ROUTE ENGINEERING AND TECHNICAL SPECIFICATIONS FOR EQUIPMENT

In adopting the output of the preinvestment surveys, suitability of the sites selected by ITU consultants to form the PANAFTEL linkages were discussed in detail at both the Addis Ababa and Lome meetings. It is crucially important to similify the operation of the PANAFTEL network as far as possible by minimizing cross-border coordination problems between administrations as well as applying uniform signaling systems. The ITU, in compliance with general agreement at the Addis Ababa meeting, has prepared general technical specifications for international switching ceuters, and for radio and multiplex systems that the administrations can use as a basis for their individual technical specifications. This would ensure compatibility of equipment thus enabling a homogeneous network to be established over the continent, and that is the principal aim of PANAFTEL.

FINANCING OF THE PROJECT

The original estimated cost of the PANAFTEL network as of November 1972 was approximately 100 million U.S. dollars for the foreign part. But owing to world inflationary trend this estimate would now be exceeded considerably.

Several financial institutions and bilateral aid agencies were invited to participate at the Meeting on Implementation of the Pan-African Telecommunication Network (Addis Ababa, Oct.–Nov. 1972). The meeting adopted two resolutions; namely: "Financing of the Pan-African Telecommunication Network Implementation" and "Establishment of an Investment Fund" aimed at forming a basis for followup of the preinvestment survey to locate sources of finance that would enable the complete network to be funded as a whole unit. In July 1974 a meeting of several multinational and bilateral financial institutions was convened in Geneva under the coordinating effort of the Coordinating Committee for PANAFTEL Network Implementation (i.e., OAU, ITU, ECA, and ADB). The output of this meeting was that in several cases definite financial commitments to finance certain sections of the network were made by various donor countries.

As a result of these efforts as well as those carried out independently by administrations, financing has been secured for most of the network mainly from ADB, IDA, and IBRD. Several bilateral financing agreements will also be applied enabling some parts of the network to be in service during early 1976.

TECHNICAL SEMINARS

A further output of the preinvestment survey was the recognition and subsequent adoption of Resolution 3 "ITU Microwave and Switching Seminars" at the Addis Ababa meetting. The purpose was to improve the technical knowledge of the staff of the administrations in the planning of systems and subsequent bringing into service of equipments to be used.

Four seminars were envisaged and they have all been held at Abidjan, Dar-es-Salaam, Lusaka, and Yaoundē, respectively, covering radio and transmission, switching, traffic, tariff, and signaling fields. These seminars have provided invaluable knowledge and open discussions among middle level technical staff necessary for the planning, implementation, and subsequent operation of the PANAFTEL network.

They have provided the much needed forum where technical staff discuss in detail the meanings and implications of the various CCIR/CCITT recommendations necessary for homogenizing the technical standards and operational procedures for PANAFTEL. In particular, the recommendations of the ITU's Tariff Study Group for Africa (TAF, Lagos, 1971) have now been adopted as CCITT Green Book Recommendations D200 R and D201 R. In addition, there was the desire to adopt a uniform signaling scheme throughout the PANAFTEL network. It is quite significant to note that all administrations have agreed to adopt the CCITT signaling system R2. The Yaoundē Seminar dealt with tariff and signaling to be used in PANAFTEL in detail and came up with common proposals to be applied in employing signalling system R2. Implicit in these proposals is the coordination that mnst be effected between administrations before bringing into service part or the complete network, and this is in agreement with the political aim of PANAFTEL.

STATE OF IMPLEMENTATION OF THE PANAFTEL NETWORK

Current information on PANAFTEL implementation is shown in Fig. 3 and indicates that by 1980 virtually all of the originally proposed and surveyed network will be in service. Tenders for a good part of the network have been called and many are either awarded or are under adjudication at the present time with the civil works part having beeu started earlier in a good many cases.

At the recent Conference of African Telecommunication Administrations (Kinshasa, Zaire, Dec. 3-16, 1975) the subject of African telecommunications was considered in every possible extent. Several new routes were confirmed as essential extensions to the PANAFTEL network, and firm requests for survey by ITU were made to ensure that the extension routes would also be engineered to the CCIR/CCITT internationally recommended technical standards. These routes are also shown in Fig. 3. The network therefore continues to expand.

The project is at an advanced stage in its progress towards complete implementation and to assist administrations with implementation, ITU has established a project implementation coordinating team based at Addis Ababa consisting of experienced switching and transmission engineers who could be attached to administrations on short-term missions to assist with equipment tender adjudication, installation, and acceptance testing, apart from regularly keeping up with all coordination activities necessary for ensuring that PANAFTEL is evolved as a technically coherent network with the best possible financing arrangement.

FUTURE OF THE PANAFTEL NETWORK

The traffic routing over the PANAFTEL network will be influenced by the quality and the flexibility that this network will provide, security demanded by some countries, and the cost of setting up regional circuits. Some countries are not covered at all by the original PANAFTEL network proposal and some of the longer links in PANAFTEL (e.g., from Alexandria to Cape Town, 8200 km) are several

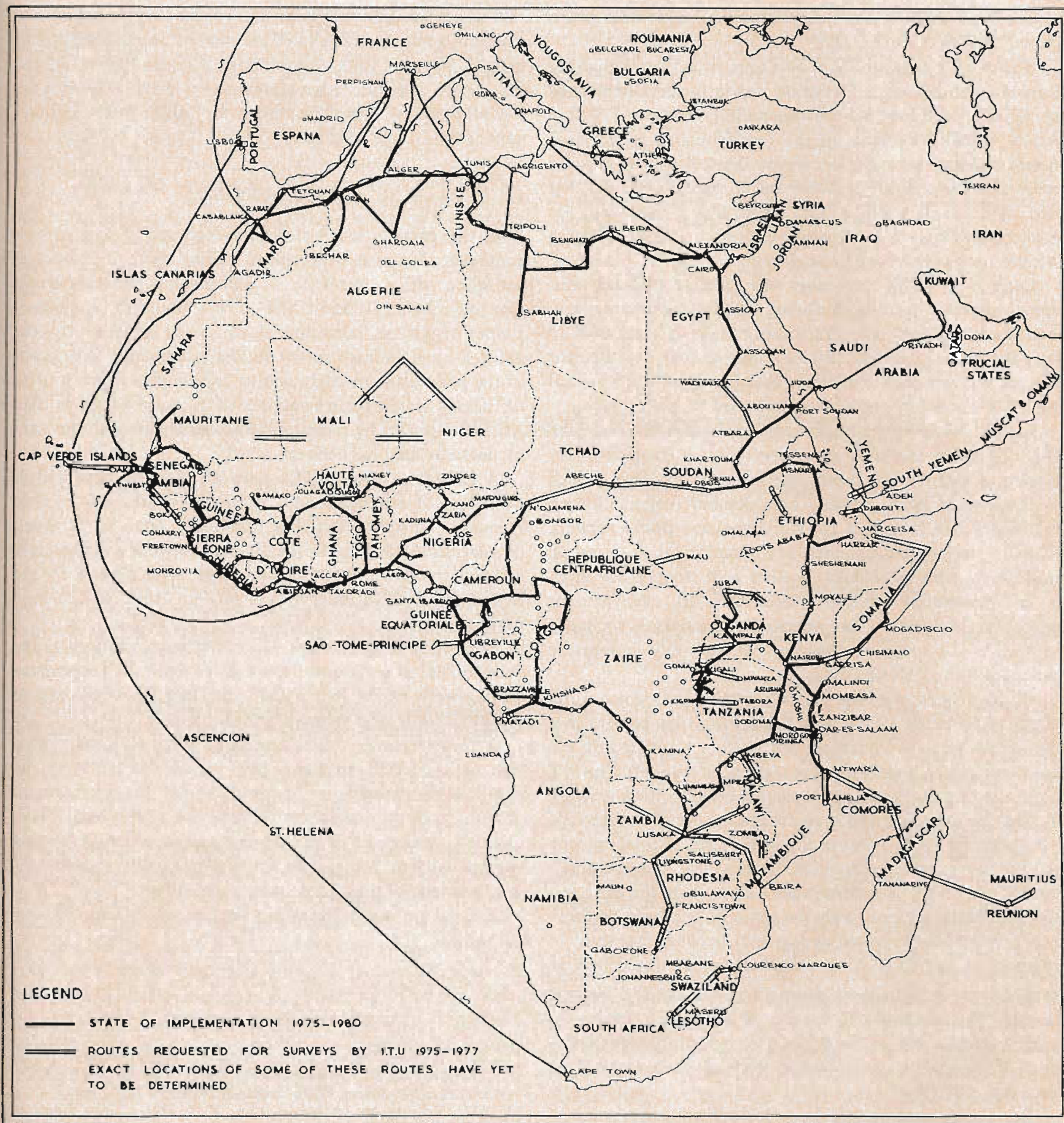


Fig. 3. Pan-African telecommunication network.

times longer than the CCIR/CCITT hypothetical reference circuit, and thus traffic routing over such distances connecting several switching centers might degrade the circuit quality considerably.

As a terrestrial network, PANAFTEL consists, essentially, of a minimum of interstate links necessary for the evolvement of a complete system and cannot be expected to meet all the inter-African telecommunication needs even at its completion. The overall inter-African links thus enabled by this network will consist of several composite channel capacities. Therefore, various levels of traffic congestion will tesult.

Furthermore, PANAFTEL is likely to take several years to implement in total, as the necessary economic support and manpower capacities of each of the participating couutries are so diverse. Present inter-African traffic forecast may change dramatically over the next few years, thus necessitating a complete network replanniug. It is also true that even when all the necessary materials are available, terrestrial networks usually take considerably longer to build while traffic growth continues day by day.

However, it is sufficient at this time to recognize that the PANAFTEL network is at its first step in the development of an efficient and modern telecommunication network within Africa, because it must be the foundation of an efficient future regional network for Africa. That is why it requires every possible support available and it should he completed first. A future network to share traffic with it and which has greater flexibility to cope with the diverse needs of emerging African nations will need to be planned.

Consequently, the next stage will be the consideration of complementary systems including satellite communication. Additional national and intercountry trunk circuits need to be provided as time goes by. Each step of such development will go hand in hand with the development of traffic which itself is generated by the facilities provided by earlier steps.

A brief study of traffic forecasts over the African region (Fig. 2) clearly indicates the necessity for a complementary system to PANAFTEL during the next decade. One of such systems would most probably be a domestic communication satellite system for Africa [6] working to and from a network of earth stations and operated as a complement to terrestrial microwave radio relay links together with remnant HF links. A communication satellite system with its overwhelming advantage of flexibility and relative inexpensiveness of implementation and operation would be the most ably equipped to supplement the PANAFTEL.

In this way most of the longer terrestrial links which suffer circuit degradation arising from link transmission performance difficulties may be routed via the satellite together with circuits over which greater touting security is required. This will be in addition to normal traffic sharing between these systems. Taking the foregoing into account and the current techuological design efforts to improve the whole field of satellite communication systems technology, in particular, the spacecraft design, substantial cost advantages will result in the earth sector, i.e., earth stations, with the same or improved performance. Therefore, it would appear that between one-third to one-half of the total African regional traffic would best be routed via an African domestic satellite system during the next decade. This is illustrated by Fig. 2 and in a paper by the author read at the Institution of Electrical Engineers Conference on Satellite Communication Systems Technology (London, Apr. 1975) [6].

But the African people have decided with regard to an African domestic satellite communication system. At the Conference of African Telecommunication Administrations (Kinshasa, Dec. 3-16, 1975) a resolution was adopted calling for an urgent feasibility study of an African satellite communication system for common carrier communication and educational broadcasting. The conference also discussed in detail special measures necessary for the development of telecommunications in the rural areas and decided on close cooperation between administrations to share existing and new experience such as may be obtained from the radio-Call network operated in East Africa for rural telecommunications.

The next decade should see the virtual completion of original configuration of PANAFTEL and the development of its extension by a mixture of systems inclnding an African domestic satellite communication system as the main to provide for the principle of complementarity to PANAFTEL and communications to the rural areas.

CONCLUSIONS

In this paper a brief historical background of African telecommunications has been traced leading up to the conceptualization of a pan-African telecommunication network. The role of the ITU and UNDP in first mounting preliminary studies of African telecommunications and subsequently, the detailed preinvestment survey studies is described. The output of the preinvestment study and its followup to locate sources of funding for the implementation of the network and to train African engineers by means of technical seminars on the techniques to be used has been described.

A completed PANAFTEL network alone is visualized as consisting of interconnected national networks with various composite channel capacities enabling several traffic levels of congestion to occur in the regional network and therefore must be considered, in its present stage, as only a step for the development of an efficient and modern telecommunication network.

The next stage is seen as inevitably consisting of the PANAFTEL as a terrestrial network as well as a complementary network having greater traffic handling flexibility, ease of implementation, and subsequent operation.

A complementary telecommunication network that would best contribute to an inexpensive method of satisfying the continuously changing traffic matrix of the African continent as well as provide adequate capacity for educational broadcasting is considered to be a domestic satellite communication system [6] and is suggested for implementation possibly towards the end of the next decade at the earliest.

A feasibility study for such a satellite system has now been authorized.

REFERENCES

[1] P. O. Okundi, "Proposals for an African domestic communications satellite system," Telecommunications Group Rep. 117, Univ. of Essex, Colchester, Essex, England, 1974.
[2] ITU Meeting on Implementation of the Pan-African Telecommunication Network (Addis Ababa, Ethiopia, Oct. 30–Nov. 10, 1972.
[3] ITU Pan-African Telecommunications Network, Regional Meeting, West African Working Group, Lomé, Togo, Apr. 17–19, 1973.
[4] ITU Plan of Lagos 1971: General Plan for the Development of the Regional Network in Africa 1970–1978, Geneva, Switzerland, 1971.
[5] ITU minutes of the coordination working meeting for PANAFTEL implementation, with OAU, ECA, ADB, IBRD, and several funding sources (Geneva, Switzerland, July 9, 1974).
[6] P. O. Okundi and B. G. Evans, "AFROSAT: Proposals for an african domestic satellite communication system," in *Inst. Elec. Eng. Int. Conf. Satellite Communication Systems Technology* (London, England, Apr. 7–10, 1975), Inst. Elec. Eng. Conf. Publ. 126.

Philip O. Okundi was born in Homa Bay, Kenya, on May 5, 1941. He received the Diploma in electrical engineering from the Polytechnic of Central London, London, England, in 1966, and the M.Sc. degree in telecommunication systems from the University of Essex, Colchester, Essex, England, in 1974.

From 1966 to 1968 he undertook two years of industrial professional post-graduate training with the East African Posts and Telecommunications Corporation, Nairobi, Kenya. Then from 1968 to the present time, he has worked in the Telecommunications Department of the East African Posts and Telecommunications Corporation holding various positions of responsibility at both regional and East African headquarters levels. In 1973 he was appointed Assistant Director General, Telecommunications, and Engineer-in-Chief of the East African Posts and Telecommunications Corporation, a position he holds to the present time. His interests lie in radio propagation, satellite communication systems, and the role of telecommunications in regional development.

Mr. Okundi is a member of the Institution of Electrical Engineers (London) and is a Chartered Electrical Engineer (C.ENG., M.I.E.E.). He is also a member of the Institution of Engineers of Kenya and a Registered Professional Engineer in Kenya (R.ENG., M.I.E.K.).

Educational Television and Development in Iran

LAWRENCE T. BREKKA, MEMBER, IEEE, AND BRUCE B. LUSIGNAN

Abstract—Some developing nations, such as Iran, have the resources for rapid economic development. Typically, that development requires very large and rapid expansion of education and training programs. An educational television (ETV) system is shown to be an effective tool for providing the needed expansion as long as it is used primarily for training adults. This conclusion is based on a detailed analysis of successful ETV operations in the United States and Great Britain. Specific functions needed for effective ETV application are identified, and organizational guidelines are proposed.

INTRODUCTION

THIS paper examines the potential use of educational television (ETV) to train and educate large numbers of people in support of rapid economic development. The discussion focuses on the case of Iran, which is in a unique position to develop rapidly, based on its expected oil revenues over the next 20 years. If that development is to be fully achieved, Iran must increase its supply of skilled manpower at a rate greater than is possible with conventional education and training programs. An ETV system provides a means of meeting these training needs. Furthermore, the oil revenues enable Iran to support the expansion of its ETV production and distribution system, and to carry out the large education and training programs needed for development. The following sections describe Iran's need for trained manpower, the use of ETV to train large numbers of people rapidly with a small number of academically qualified instructional staff, and the factors important for successful implementation.

Manuscript received January 19, 1976; revised February 18, 1976. This work was supported by National Iranian Radio and Television (NIRT). The views expressed are those of the authors and do not necessarily reflect official Iranian government policy.

The authors are with the Communication Satellite Planning Center, Stanford University, Stanford, CA 94305.

IRAN'S MANPOWER NEEDS

Based on present projections of Iran's oil revenues, the per capita gross national product (GNP) in the country can be expected to rise from about \$570 in 1972 to nearly \$5000 in 20 to 25 years as shown in Fig. 1 [1]. Thus Iran can expect to have a GNP comparable to Western Europe in 20 years. These projections, however, make one major assumption: that the skilled manpower needed to make industry, commerce, and agriculture function in the expanded economy will be available. This could be a poor assumption. An assessment was therefore made of Iran's future manpower needs to find out how difficult it will be to educate and train a sufficient number of people.

Since the projected 1992 GNP is comparable to that of many developed countries, the distributions of skills and occupations in a number of those countries were used to estimate Iran's needs. A "typical" distribution is shown in Table I, based on data from France, Germany, the United Kingdom, and the United States. Table II shows how Iran's work force would appear in 1992 if it has the typical developed-nation distribution, and compares those values to the present. The largest numerical change needed is in clerical support personnel where more than two million must be added to the workforce between 1977 and 1992. On a percentage basis, the most severe shortage is in college-trained administrative and managerial personnel, where there should be a factor of 14 increase.

The problem of developing a skilled workforce is complicated by a high incidence of illiteracy, particularly in rural Iran. In 1967, some 86 percent of the rural population was still illiterate. An intensive campaign to eradicate illiteracy has been under way for a number of years, but some 75 percent of the population in the rural areas is still illiterate. It is estimated that in the 10–44 age group this represented approximately

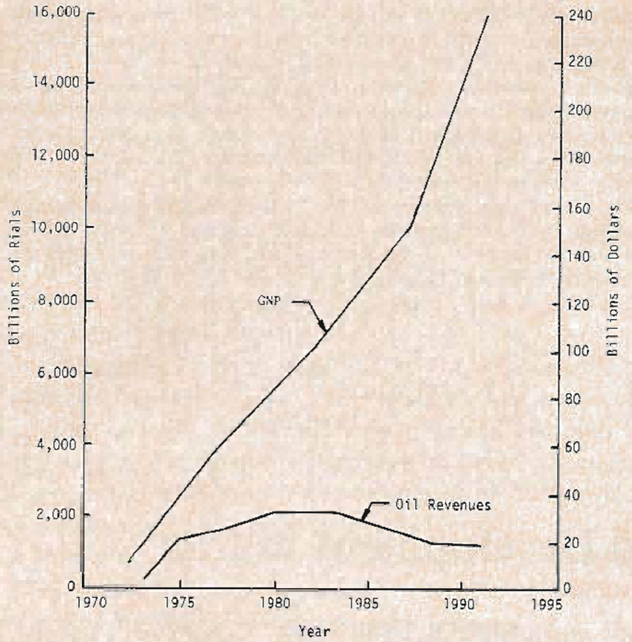


Fig. 1. GNP and oil revenues through the year 1991 (from [1, tables 2 and 6]).

TABLE I
DISTRIBUTION OF WORK FORCE BY SECTOR IN INDUSTRIALIZED COUNTRIES

Percent Workforce in Sector	France (1968)	German Federal Republic (1970)	United Kingdom (1971)	USA (1973)	"Typical"
1. Professional, Technical and Related	11.4	9.8	11.1	13.2	11%
2. Administrative and Managerial	2.7	2.2	3.8	9.6	4%
3. Clerical and Related	11.7	17.6	17.9	16.7	16%
4. Sales	7.6	8.9	9.0	6.2	9%
5. Service	8.4	9.5	11.8	13.0	12%
6. Agriculture, Animal Husbandry, Forestry, Fishing, Hunting	15.3	7.7	3.0	3.4	11%
7. Production, Transportation Operators, Laborers	34.6	36.3	39.9	34.6	37%
8. Unclassified	5.0	0.9	2.5	2.0	—
TOTAL WORKFORCE (millions)	20	26	25	91	—

Note: Country columns do not add to 100 percent. Some categories, such as "Foreign Workers," are uot included because they are not relevant.

6 200 000 people in 1972. Plans for the expansion of the elementary school system in Iran are expected to stop the influx of new illiterates into the population by 1982. Before then, however, an estimated 1 070 000 children will have become additional candidates for literacy programs, making a total of 7 200 000 people requiring training in literacy.

Fig. 2 summarizes our estimates of training needs, including literacy, for Iran over the 15-year period between 1977 and 1992. Examination of Iran's present education system and its plans for expansion show that conventional training and education methods are not going to be able to produce the required number of trained people. For example, the number of college graduates in Iran over the next several years, including those returning from abroad, will be less than half of what is needed. Some other means, therefore, has to be found which will enable these training rates to be achieved over the next 15-year period.

TABLE II
DISTRIBUTION OF IRAN'S WORK FORCE BY OCCUPATIONAL CATEGORY (IN PERCENT AND IN THOUSANDS OF WORKERS)

OCCUPATION	YEARS 1345 (1966)	1351 (1972)	1356 (1977)	(Estimated) 1371 (1992)
1. Professional, Technical and Related	2.7% 203	4.6% 423	6.7% 706	11% 1804
2. Administrative and Managerial	0.1% 12	0.2% 22	0.4% 46	4% 656
3. Clerical and Related	2.7% 201	2.6% 240	3.1% 325	16% 2624
4. Sales	6.7% 504	7.8% 718	8.4% 883	9% 1476
5. Service	6.7% 510	11.6% 1058	10.8% 1143	12% 1968
6. Agriculture, Animal Husbandry, Forestry, Fishing, Hunting	41.3% 3137	39.6% 3620	33.8% 3570	11% 1804
7. Production, Transport Operators, Laborers	26.8% 2032	33.3% 3048	36.8% 3887	37% 6068
TOTAL WORKFORCE	5,169	9,129	10,560	16,400

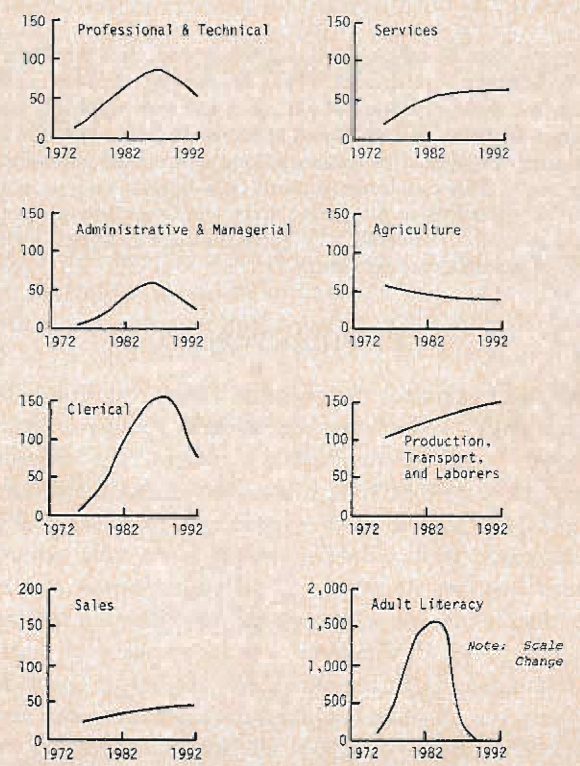


Fig. 2. Graduates of education or training required for projected eeonomic growth (in thousands).

EDUCATIONAL TELEVISION

ETV has the potential of helping Iran meet its needs of trained manpower. There are many ways, however, in which it could be applied, and it is important to understand the various approaches so the best one can be selected. In order to gain this understanding, we examined a number of successful experiences of ETV use ranging from elementary and secondary grade levels to postsecondary formal and informal education [2].

As a result of our assessment, we concluded that *the most effective use of ETV for major and rapid expansion of the nation's total educational and training system is as a replacement of live lecture to adult students.* That use of ETV produces the greatest increase in the number of people that can be reached by training and education programs.

At the elementary and lower secondary levels, ETV permits an increase of about one-seventh in the numbers of students that can be reached by a given number of teachers and teacher aides. This estimate is based on the experience of school districts in Anaheim and Santa Ana, CA [3].

Washington County (Hagerstown), MD, which operates an extensive ETV system for its elementary and secondary schools, is moving away from grouping of classes to reduce staffing needs and is emphasizing enrichment of the curriculum. The only reduction in teaching staff made possible by ETV is in specialty areas such as art and music [4].

In contrast to these small changes in student-teacher ratios, ETV at the postsecondary level can increase the number of students taught by an individual instructor by factors of 2, 3, and even 4. These results are based on case studies of the following postsecondary institutions:

Chicago TV College, Chicago, IL, in operation since 1956, provides the Associate of Art degree and includes vocational education; programs are transmitted by VFH broadcasting.

Coast Community College District, consisting of Orange Coast College and Golden West College, Orange County, CA, has offered ETV courses since 1973 via UHF broadcasting.

Outreach Consortium, consisting of 18 institutions of higher education in Orange and San Diego Counties, CA, had its first course offering in Sept. 1972, via UHF broadcasting.

Stanford University Engineering Telecourses, Stanford, CA, has broadcast postgraduate engineering courses over the Stanford Instructional Television Network to area firms since 1969, using an Instructional Television Fixed Service system broadcasting at 2500 MHz and requiring special receivers.

Association for Continuing Education (ACE), has broadcast postsecondary courses from San Francisco Bay Area educational institutions to area firms since 1969; ACE uses the Stanford Instructional Television Network.

Oregon State University has used cable system to transmit courses on- and off-campus since 1966.

British Open University, using ETV as part of a mixed media instructional package, has been in operation since Jan. 1971.

Another characteristic of the postsecondary use of ETV is that less highly trained people can be used as "mentors" for direct interaction with the student. Thus even greater expansion is possible in the number of students reached by a given size academically qualified staff. At Oregon State University, one principal instructor was able to manage an enrollment of 700 in a biology course, with the help of 22 teaching assistants who were either advanced undergraduates or graduate students with a Bachelor's degree. The teaching assistants spent an average of eight hours per week on the course. This includes meeting with groups of 30 students for two hours per week, one in recitation, and one in the laboratory.

The possibility of using less highly trained mentors to interact with the students is particularly significant for Iran because there are far more people in that country qualified to be mentors than there are people qualified to be college or university faculty. Also, it is possible for the mentors to be involved with ETV on a part-time basis, as shown by the amount of time spent by the teaching assistants at Oregon State. This means that mentors can be drawn from working people with expertise in the subject area of the course. In rural areas this is particularly important because often there will not be large enough classes to justify any full-time instructional staff.

The much greater increase in ETV students for a given size academic staff at the postsecondary level indicates that ETV resources are better spent there than for elementary and secondary programming. This conclusion is strengthened by the fact that the 14 percent increase in students reached by ETV at the elementary and secondary levels requires grouping of classes. That is not feasible for the large portion of Iran's population which is widely dispersed in rural areas.

IMPACT OF ETV ON TRAINING RATE

Concept

The preceding examples indicated quite clearly that ETV can increase the number of people taught by a given-size academically qualified instructional staff. What is extremely important for most developing countries is that ETV also provides for more rapid expansion of the instructional staff than is possible with conventional training programs. This can happen because the recent graduates from a training program can be used as mentors in an ETV course. Normally, instructional staff must have a number of years of additional training beyond the level of the program they teach.

The concept of how these factors affect training rates is shown in Fig. 3 for the case of teacher training. In the conventional education system, students pass through the elementary grades and enter teacher training institutions. Graduates of the teacher training institutions can then either take positions in the elementary and secondary schools, or, if qualified, continue studying for an advanced degree. The latter, after spending several more years in advanced studies can join the faculty of the teacher training institutions. The conventional student-staff ratio in that case is 30:1.

With ETV, however, the major portion of the teacher training institution's instructional staff are mentors—if 10 mentors are used with each principal instructor, mentors would account for more than 90 percent of the staff. Instead of waiting years to join the instructional staff, recent graduates of the institution can be prepared for mentor roles in a matter of months, much as graduate students are used in conventional colleges and universities. Thus, the major portion of the staff can grow quite rapidly, limited only by the availability of prin-

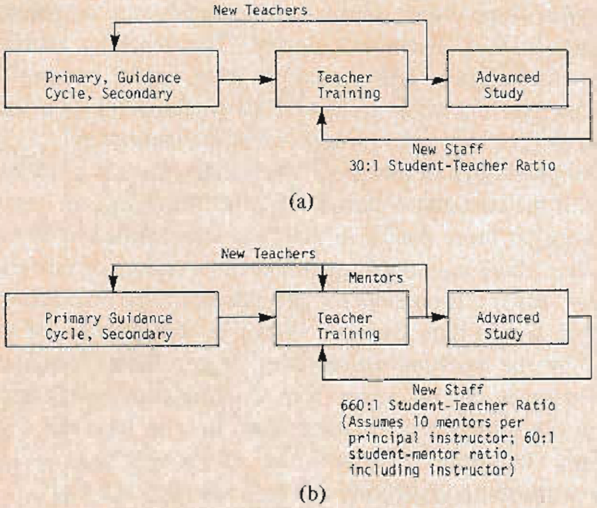


Fig. 3. Acceleration of teacher training with ETV. (a) Conventional system. (b) ETV system.

cipal instructors. In examples studied for teacher training in Iran, the rate of training was estimated assuming 10 mentors per principal instructor and 60 students per mentor as shown in Fig. 3. The training rate became very large very quickly and training goals were met before the availability of principal instructors could become a limiting factor.

Specific Example–Teacher Training

Training of elementary and secondary teachers was selected for detailed examination of the effects of ETV on training rates. In Iran, as in any developing nation, the shortage of qualified elementary and secondary teachers is a critical limitation in the rapid expansion of education and training programs. Therefore, the training of new teachers and the provision of in-service upgrading for existing teachers has high priority.

The basic structure of Iran's education system is described in Fig. 4. The major divisions are the preprimary, which includes kindergarten; the primary grades one through five; the guidance cycle, grades six, seven and eight; and the secondary school level of grades nine through twelve which can track either academic or vocational career interests. The secondary schools have been reorganized since publication of Fig. 4, but the changes are not critical for this example. The postsecondary level includes junior colleges, four-year colleges and universities, and graduate schools.

The training programs in Iran reflect the division of the elementary and secondary grades into primary, guidance cycle, and secondary:

1) The principal source of primary grade teachers is a two-year Normal School program which substitutes for the 10th and 11th years of schooling at the secondary level. Because of the intensity of the program, the Normal School certificate is considered the equivalent of a high school diploma.

2) Guidance cycle teachers are trained in special centers. The program is two years in duration and results in au Associate degree for the graduates.

3) The nominal criterion for teaching in a high school is a Bachelor's degree. In practice, this has not been satisfied due to the lack of people with Bachelor's degrees.

The example is based on an estimated need for teachers in Iran shown in Fig. 5. The data in the figure are representative in that there are more teachers than indicated, but those not shown are considered to be less than adequately prepared for their jobs, and in need of further training. To simplify the analysis, it is assumed that they need a program of training eqnivalent to that of new teachers. Table III lists the specific enrollments and staffing assumed for the starting year of the analysis, 1977, for both the elementary and secondary schools and the teacher training institutions.

Fig. 5 also shows the results that might be expected from conventional training programs. It would take 13 years to develop fully qualified staff and have 100-percent enrollment in the nation's primary grades. The same goal is reached in 9 years for the guidance cycle, reflecting major emphasis by the government on developing conventional guidance cycle training centers. For the high schools, the goal is much more than 15 years away, reflecting the small number of Bachelor degree graduates in Education in Iran.

Table IV summarizes the ETV teacher training program used in the example in terms of instructional staff credentials. Student-mentor ratios of 60 : 1 are assumed. The results are shown in Fig. 6, with prinicpal results as follows:

1) The primary grades can have enough teachers with at least a Normal School certificate to accommodate 100-percent enrollment in 6 years instead of 13. Some of those teachers can have Associate of Arts degrees, a benefit going beyond what would be achieved with the conventional training programs.

2) Little or no change occurs at the guidance cycle level. This is due to the high priority already given to conventional guidance cycle teacher training.

3) High school staffing with Bachelor degree graduates to accommodate 100-percent enrollments is accomplished in 13 years compared to "much longer than 15 years" with conventional education. Sufficient staff for 100 percent of incoming students can be provided after only 3 years by employing Associate degree graduates until more Bachelor degree graduates become available.

The results presented here are insensitive to major errors in the initial conditions. A 100-percent error in the estimate of available qualified primary grade teachers would result in a year or two difference in the final outcome. The starting point for qualified secondary school teachers is so low that a large error in the estimate of the number actually available would also make little difference in the conclusions reached from the analysis.

The major weakness of the analysis is the assumption that as many trainees as are needed would be available for teacher training. At the point of peak training this would require that some 20 percent of Iran's high school students enroll in teacher training programs to maintain the rate of training possible with ETV. This problem can be resolved by placing strong emphasis on in-service training of teachers who are already working but not adequately trained, and by training people in other occupations to be teachers.

For Iran, or any developing nation, teacher training is but one of the many disciplines that have to be accounted for in major training programs. In order to properly allocate training

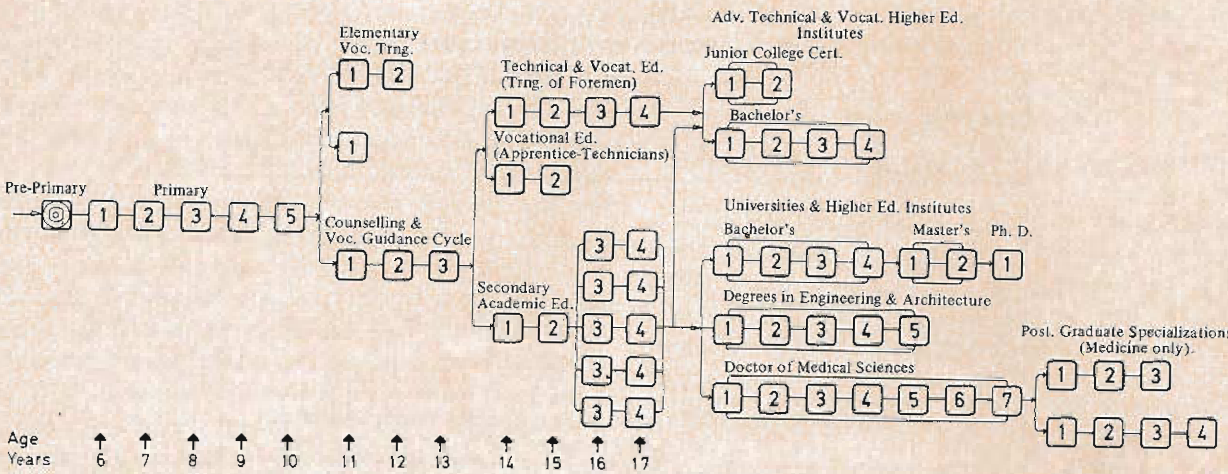


Fig. 4. Chart of the system of formal education in Iran. (The new system, see [6].)

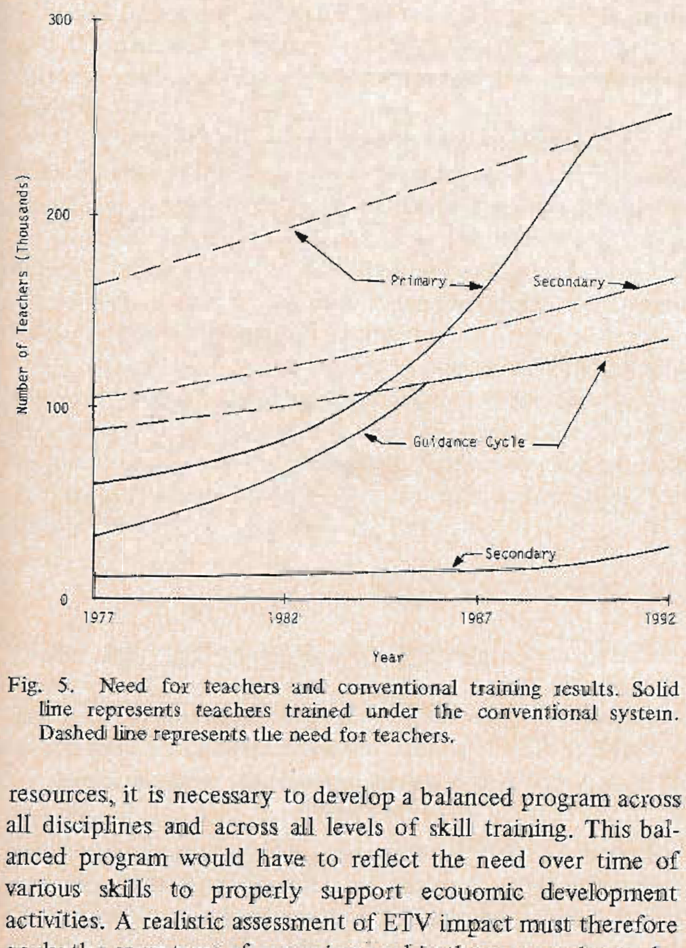


Fig. 5. Need for teachers and conventional training results. Solid line represents teachers trained under the conventional system. Dashed line represents the need for teachers.

resources, it is necessary to develop a balanced program across all disciplines and across all levels of skill training. This balanced program would have to reflect the need over time of various skills to properly support ecouomic development activities. A realistic assessment of ETV impact must therefore apply the same type of reasoning used in these examples to the range of training programs needed. Work of that nature is proceeding at Stanford University.

IMPLEMENTATION

The preceding sections have demonstrated the potential of ETV for rapidly accelerating the training of skilled manpower. Whether or not such a program could be effectively implemented is another issue.

Implementation of ETV involves: 1) production of video and support material, 2) delivery of that material, and 3) local presentation. This article discusses key factors relating to delivery and local presentation, and guidelines for the organization of an ETV system which accounts for these factors. Production is not dealt with, but the interested reader can find it discussed in detail in [2].

Delivery

The delivery of support material such as texts and laboratory kits will have to rely on the Iranian postal system or supplementary services. Although the postal service is poor in rural Iran, support material can be sent with enough lead time to ensure its availability when needed.

The delivery of video material has two components: local and national. At the local level the key consideration is the need for major recording and replay activities. The volume of programming needed to support a major ETV effort, on the order of tens of thousands of hours, precludes major reliance on over-the-air broadcasting. It will be necessary, therefore, to have local recording of programs and replay over cable networks, and on individual videotape and videocassette players, as well as over standard VHF stations.

At the national level in Iran, the problem is to distribute material to several thousand widely distributed reception sites. The least expensive way of doing this is by satellite. An optimal communication satellite and ground station system which will provide nationwide television distribution for Iran is described in [5].

In addition, the satellite system will provide radio, telephony, data, and facsimile transmission. These services are important for providing effective ETV programs, particularly in rural areas. Radio, for example, provides a means of supplementing television broadcasts with multiple language tracks for people not fluent in the national language. The other services make it possible for the local mentor to interact with the principal instructor and handle administrative functions.

The technical characteristics of the satellite system and ground stations are summarized in the Appendix.

Local Presentation

The major area of concern for successful implementation of ETV is in rural communities. The examples of ETV successes described earlier involve education and training programs for

TABLE III
ENROLLMENTS AND STAFFING–1977

A. Enrollments and Staffing in Schools

Grade	Enrollment (1000)	Population (1000)		Instructional Staff and Credentials: Less Than Normal School	Normal School Certificate	Associate Degree	Bachelor's Degree	*** Literacy Corps
5	804	914	Primary*	64,000	60,000	0	0	23,000
6 7 8	525 510 495	887 861 836	Guidance Cycle	0	18,000**	• 33,000	0	0
9 10 11 12	344 314 305 296	812 788 765 743	Secondary School	0	30,000	0	12,000	0

* Instructional staff are shown for grades 1-5.
** Normal School Certificate or High School Diploma.
*** Members serve two years in lieu of military duty. Assumed to phase out when not needed.

B. Teacher Training

NORMAL SCHOOL: Enrolled	NORMAL SCHOOL: Staff (BA, BS)	GUIDANCE CYCLE TRAINING CENTER: Enrolled	GUIDANCE CYCLE TRAINING CENTER: Staff (BA, BS)	COLLEGE/UNIVERSITY: Enrolled BA, BS	Enrolled MA	Enrolled Ph.D*	Staff MA	Staff Ph.D
5,610	187	11,400	380	1,020	25	1	24	11

*No Ph.D. program assumed for 1977. Assumes one student per year receives Ph.D. abroad.

TABLE IV
ASSUMED ETV INSTRUCTIONAL STAFF

INSTITUTION	CREDENTIALS: Principal Instructor	Mentor (10/Instructor)
Normal School	B.A.	Graduate of Normal School
Guidance Cycle Training Center	B.A.	Graduate of Guidance Cycle Training Center
College and University	M.A.	B.A.

relatively well-educated people. Even in Iran, recent use of ETV by Pahlavi University in the urban area of Shiraz and its surrounding communities showed excellent results [6]. The presentation of three foundation courses, business economics, psychology, and Farsi, the national language, attracted 6000 students of whom 2000 completed the courses and 1800 passed the final exams.

In the rual areas, by contrast, a large portion of the population is accustomed to a life far removed from that of a developed nation. Many people have not even been exposed to television, let alone participation in an intensive education or training program. Research on the social and cultural characteristics of rural Iranian communities and the effectiveness of conventional training and education programs has identified potential problems with the introduction of ETV.

Some of these problems, such as the opposition of religious leaders to the introduction of new ideas, high rates of illiteracy, different native languages, and different learning habits, are primarily related to the selection of content, and the design of the video presentation and the support materials. Resolution of these issues requires detailed planning and research activities such as those described in [2]. Others involve local community reaction to the introduction of new organizations and new progams.

There are basically two types of community reaction problems: those associated with the acceptance of outside organizations, and those affecting traditional concepts of accepted behavior in the community. Outside experts and advisers, whether Iranians from cities or different rural areas, or non-Iranians, have difficulty in gaining the confidence of the local community. People in the villages may feel that outsiders do not fully understand or sympathize with their problems or that the outsiders are not competent because their backgrounds and affiliations are unknown. In Iran, doctors employed by the government and assigned to rural areas have found extreme difficulty in being accepted into local communities. Even rural Iranians assigned to clinics in areas outside their own hometowns and villages were often rejected. A key factor to solving this problem appears to he in the selection of local mentors. Respected members of the community can play an important role in establishing trust in the new programs.

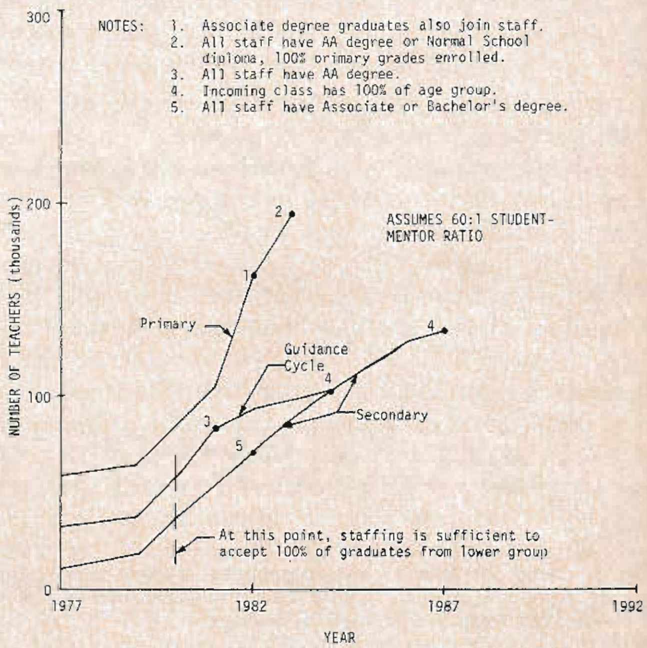


Fig. 6. ETV used to train primary, guidance cycle, and secondary teachers.

One problem related to accepted behavior concerns the education of women. Traditionally, women have been isolated from men, especially men who are not members of the immediate family. If women are reluctant to mingle publicly with men in their first encounters with unfamiliar institutions, classes could be held separately with mentors of their same sex. Where this is not feasible, presence of both men and women mentors may alleviate the problem.

These problems emphasize the importance of the local mentor. Even though there are issues related to the institution sponsoring the training programs and their physical location, the principal agent for assuring local acceptance and effectiveness of ETV is the mentor. Individuals who are respected in the community, competent in the subject area, and sensitive to the concerns of the people should be selected.

Organization Guidelines

Based on the concepts of ETV use presented in this paper, and the problems of implementation discussed above, organizational guidelines can be drawn for use by all developing nations.

1) ETV course design and local presentation should be the responsibility of organizations already conducting conventional programs. These agencies have the knowledge of the subject area, an understanding of local community needs, and, typically, have a local presence. The best example of this is the world-wide use of agricultural extension agents by Departments and Ministries of Agriculture.

2) The delivery of the television portion of ETV courses, however, should be the responsibility of a single agency. This is primarily a matter of cost and efficiency; duplication of technical services is not warranted. Similar conclusions hold for radio, telephone, data, and facsimile transmission, and library services.

CONCLUSION

For Iran and other developing nations with sufficient resources, ETV can quickly provide large-scale training programs to support rapid economic development. The key factor is that the ETV be oriented to the training of adult students.

Local mentors are needed to provide interaction with students if the full expansion capability of ETV is to be tapped. Particularly in rural areas, the selection and training of mentors who are respected members of the local community is expected to be an important element in assuring the acceptance and effectiveness of ETV.

In order to ensure the best use of existing expertise, understanding of local needs, and local presence, the design and local presentation of ETV courses should be the responsibility of the organizations already conducting conventional training programs. Communications services, by contrast, are suited for centralized operation due to cost and efficiency considerations.

Finally, a full range of television, radio, telephony, data, and facsimile transmission services can play a major role in the implementation of smoothly functioning ETV programs. Satellite systems offer a means of providing such services more economically and quickly than terrestrial means, particularly in the rural areas of developing nations.

APPENDIX

SATELLITE/GROUND SYSTEM DESCRIPTION

A satellite system design has been developed which could provide television, radio, telephony, data, and facsimile transmission throughout Iran [5]. The proposed system has been optimized for minimum total system cost. The resulting parameters of the baseline system are:

satellite antenna gain	35.3-dB beam center (ideal);
satellite transponder power	10 W;
number of transponders	8, minimum;
transponder transfer gain	110 dB (not including antennas);
small earth station G/T	16.5 dB/K;
antenna diameter	3.05 m;
preamplifier noise temperature	200 K;
telephony power amplifier	5 W;
number of small earth stations	12 000 (1500 per year over an 8-year period);
large earth station G/T	29.0 dB/K;
antenna diameter	9.75 m;
preamplifier noise temperature	90 K;
telephony power amplifier	35 W;
number of large earth stations	16 (4 per year over 4 years, located at major cities with population over 100 000).

This system would serve two-thirds to three-quarters of the projected 1985 Iranian population of 44 million. The optimization was accomplished by a computer program which uses direct estimates of television demand, and develops its own estimate of telephony demand from demographic and GNP information.

An essential concept in the design of the space segment is the use of a uniform transponder power level, but at a higher power level than is used on commercial satellites, thus permitting alternative use of transponders for video or telephony and data transmission to relatively small stations. This approach minimizes the overall system cost by transferring some of the performance burden from ground stations to the spacecraft. Analysis shows that 1000 to 1200 telephone channels can be accommodated in a single 36-MHz video channel. These numbers represent a decrease in radio frequency bandwidth and power at a given signal-to-noise ratio compared to previously accepted design concepts. The new values are based on the use of the following: companders and preemphasis, threshold extension demodulators with acquisition tracking capabilities; the use of voice activition to key the transmitter on only when the person is speaking.

ACKNOWLEDGMENT

The authors wish to acknowledge the contribution of Dr. N. V. Arvanitidis and S. Davenport of Intasa, Inc., Menlo Park, CA, to the survey higher education institutions. J. Bauer, a graduate student in anthropology at Stanford University, contrituted significantly to the definition of social and cultural problems with ETV implementation based, in part, on her own field experience in the Philippines and Iran.

REFERENCES

[1] F. Vakil, "A macro-economic projection for Iran," Plans and Budget Organization, distributed in NIRT Prospectus Project Seminar in Mashad, Iran, June, 1975.

[2] *Program Planning Assistance,* vol I. First Year Rep. submitted to National Iranian Radio and Television by the Communication Satellite Planning Center, Stanford Univ., Stanford, CA, Aug. 1975.

[3] *The Role of Telecommunications in the Regional Delivery of Educational Services: A Study of the Potential Use of Instructional Television for Vocational Education in the Appalachian States,* INTASA, Inc., and Battelle Columbus Lab., Nov. 1972.

[4] R. Predmore, Supervisor of TV Instruction, Washington County Schools, Hagerstown, MD, Feb. 1976, private communication.

[5] *A Baseline System Configuration for Video Distribution and Telephony,* vol. III. First Year Rep. submitted to National Iranian Radio and Television by the Communication Satellite Planning Center, Stanford Univ., Stanford, CA, Aug. 1975.

[6] Data obtained from Pahlavi University, Shiraz, Iran, Aug. 1975.

[7] *Analytieal Study on Financing of Higher Education in Iran,* Institute for Research and Planning in Science and Education, Economics of Education and Manpower Planning Dep., Tehran, Iran, May 1973.

★

Lawrence T. Brekka (M'73) was born in New York, NY, on August 23, 1940. He received the B.S. degree in aeronantical engineering from the University of Notre Dame, Notre Dame, IN, in 1957, the S.M. and Engineer degrees in aeronautics and astronautics from M.I.T., Cambridge, MA, in 1965, and the Ph.D. in engineering-economic systems from Stanford University, Stanford, CA, in 1972.

He has worked on performance analysis, and guidance and control system development for ballistic missiles and manned spacecraft at the U.S. Naval Ordnance Laboratory, White Oak, MD (snmmers, 1960–1964), M.I.T. Instrumentation Laboratory (1961–1966), and Lockheed Missiles and Space Company (1966–1969). As a member of the White House National Goals Research Staff (1969–1970) he was responsible for a study of the nation's education system At INTASA, Inc., Menlo Park, CA (1970–1974), a contract research firm, he was responsible for systems analysis work in the areas of edueation, health, and telecommunications. He is currently a Consultant to the Communication Satellite Planning Center of Stanford University, responsible for planning of educational telecommunications services, and their role in economic development. He is also Cofounder and Principal Associate of Communications Planning Associates, which specializes in rechnical, economic, and developmental planning of satellite systems.

★

Bruce B. Lusignan was born in San Francisco, CA, on December 22, 1936. He received the B.S. degree in engineering science, and the M.S. and Ph.D. degrees in electrical engineering from Stanford University, Stanford, CA, in 1958, 1959, and 1963, respectively.

He has been with the Electrical Engineering Department of Stanford University since 1962, and is now an Associate Professor. His research work has concentrated on the application of communication satellites to economic growth with special emphasis on technical system optimization and interaction between economic, business, and political factors. He also conducts policy research in the applications of television in education, the nature and role of work in different societies, social values, and world energy resources. His earlier work included government panel consulting in weather satellite programs, and arctic weather and oceanographic research. He is currently Director of the Communication Satellite Planning Center at Stanford. He is also Cofounder and Principal Associate of Communications Planning Associates, which specializes in technical, economie, and developmental planning of satellite communication systems.

Microwave System Development in India

DHARMENDRA K. SACHDEV, SENIOR MEMBER, IEEE

Abstract—This paper highlights the development aspects of microwave systems as they have grown in India. It includes discussion on early struggles, design feedbacks, and the results of a recent development effort. A note on the lessons derived from this experience is also included.

INTRODUCTION

TRADITIONALLY, most of the professional telecommunication equipment requirements of the developing countries have been met by imports from established multinational corporations in Europe, Japan, and the U.S.A. In India, however, partly due to balance of payment difficulties, but mainly due to the availability of substantial engineering talent, continuous efforts are being made by the engineering disciplines to be self-reliant. During the early 1960's, a series of developments in the field of microwave technology were undertaken to foster self-reliance and indigenous know-how.

This paper is aimed at highlighting the development aspects of microwave and associated systems as they have grown in India. In this paper, the early struggles and the resultant achievements (as well as failures), the design feedbacks from the field, and the results of a recent intensive development effort are summarized. The paper concludes with a brief note on the lessons derived from the nearly 15 years of microwave development in India.

I. ROLE OF MICROWAVE SYSTEMS IN INDIAN TELECOMMUNICATION NETWORK

The Indian telephone network is built around traffic nodes which are separated by fairly large distances. Thus, in the very initial stages not only the Posts and Telegraph Department (P&T) but also other users such as the Railways, Defence Services, etc., realized the importance of broad-band multichannel media between these nodes. The Indian long-distance network grew very rapidly in mid-1950's. Initially, preference was given to coaxial cable systems, partly because of economic factors, but principally because of the fact that the coaxial cable systems could work without nninterrupted ac power requirements over longer distances than microwave systems. This factor was quite crucial in the late 1950's as the power drains of the microwave systems available at that time were quite heavy.

In the early 1960's, however, with the fast induction of semiconductors, particularly in the baseband and IF stages of the microwave systems, the power requirements of such systems were drastically reduced. In addition, the traffic requirements called for broad-band systems in the mountainous and hilly regions where it was difficult and uneconomical to provide coaxial cable systems. Serious attention, therefore, was focused on both induction of imported microwave systems as well as on their development within the country. The policy adopted was a pragmatic mixture of straight purchase of immediately required systems coupled with high-priority indigenous development effort. Incidentally, this principle has been the cornerstone of practically all developments in India in the telecommunication field.

Manuscript received November 14, 1975; revised January 5, 1976 and February 24, 1976.

The author is with Indian Telephone Industries Ltd., Bangalore, India.

II. MICROWAVE SYSTEM DEVELOPMENT—THE FIRST PHASE

The organization entrusted with the development of the early microwave systems was the Telecommunication Research Centre (TRC) of the Indian P&T. A small nucleus of trained R&D engineers was set up by the TRC around 1961 and was put full time on the development of the first indigenous microwave system. To keep the development cycle short and also at the same time meet some of the urgent requirements of the network, the first system taken up for development was a 300-channel system in the 7-GHz band. This system utilized klystrons for both the transmitter and the receive local oscillator. Apart from this, the equipment was completely solid state. The model for this system was by and large the 11-GHz TL system of the Bell System which was just entering service at that time. The technical achievements of these early struggling days would appear trivial by today's standards of technology or compared with the efforts of large groups of R&D engineers. However, the thrill and excitement of having a first link between two microwave horns placed hardly 25 m apart from one room to another was no less than the thrill of many classic moments in the history of telecommunication development! This development was by no means original, but was in a way a major milestone for the small group of engineers who worked on this assignment with practically no specialized test equipment and entirely on their own. Above all, it speaks highly of the courage and the foresight of the higher authorities at that stage who, satisfied by this rather elementary demonstration of microwave "propagation," committed practically the entire telecommunication network of the country to indigenous development programs for a long time to come.

The 7-GHz system above was manufactured at the Indian Telephone Industries Limited (ITI) in 1967-1968, after a series of false starts mainly because of the totally new technology. The first system was inducted for limited trials around 1968-1969. The initial field results were rather discouraging but very educative; they highlighted with full force the need for reliability, particularly in the very subsystems which are almost always taken for granted by electronic designers.

Thus, the principle problems arose in the power supplies, both low voltage and high voltage, mainly because of the much higher ambient condition prevailing in the Indian repeater stations than visualized earlier. (Incidentally the same problem was found in some of the imported systems installed around the same time in the Indian environment.) Fortunately at that stage, reliable silicon power transistors were just beginning to become available and this enabled the engineers to control the problem in a short time. This 7-GHz system (Fig. 1) (which is now gradually becoming a classic one) stabilized quite well and today is providing reliable service on many spur routes of the Indian network [1], [2]. It is not capable of working on long distances due to the noise limitations; however, on few hop end-links the quality is fairly tolerable and acceptable to the users. Mainly because of the obsolescence of the klystrons and due to the limited noise performance capabilities, its production is expected to be phased out in the very near future. However, like the never-say-die TD-2 system, there is a serious consideration being given to upgrading its capacity from 300 to 600 channels by grafting on a few modern subsystems.

Broad-Band Systems–The First Attempt

The next system which was taken up for development was a broad-band 6-GHz system with a capacity of 960 channels (Fig. 2). Once again, with the exception of a traveling wave tube (TWT), the system was totally solid state [3], [4]. Many lessons learned from the 7-GHz system were kept in view during its development. Thus, a much greater emphasis was placed on maintainability and mechanical ruggedness. However, the field results were once again waiting to teach several new and harsh lessons to the system designers. The first field reports on this system were again by no means encouraging for either the development staff or the manufacturing organizations. The principle problems in this case were with the microwave local oscillators and, once again, with the high voltage power supplies. These local oscillators [5] were of straight multiplier type and therefore suffered from serious problems with regard to their noise level stability and reliability. While the noise contribution was eliminated to some extent with narrow-band cleaning filters, the reliability was improved with better matching between successive multiplier stages. However, the overall noise performance of the system still fell short of the CCIR objectives by significant margins.

Analysis of the "First Generation" Efforts

The development of the earlier generation of microwave systems briefly described above and the feedbacks from first installations drove several lessons home to the designers, manufacturers as well as systems people. First of all, it became evident that development of multichannel telecommunication systems is far more complicated than that of other types of electronic equipment. The overall system performance of a multichannel system is a very complex system function and depends on each and every parameter of the individual subsystems. The performance of the individual subsystems, in turn, depends not only on their circuit design but also on the choice of components, raw materials, and above all on the

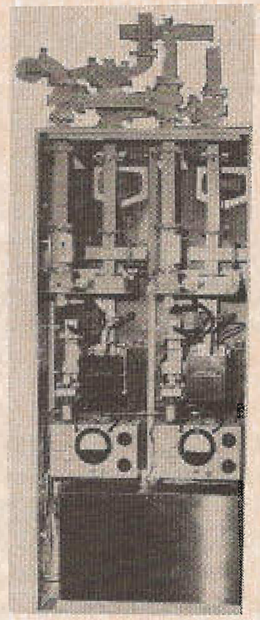


Fig. 1. 7-GHz 300-channel klystron system.

Fig. 2. 6-GHz 960-channel semi-solid-state heterodyne system with TWT.

performance margins provided for at the time of first development. However, the greatest factor which contributes to excellence in any engineering design, and possibly with greatest force for long-distance microwave and allied systems, is the strict planning of the overall development-cum-production cycle in an unified manner, preferably under one roof. The time-proven concepts of progressive screening of mechanical components through go–no-go gauges is very much applicable to overall system development cycles as well. Specifically, long before the systems are put to any large-scale utilization, it is necessary to assess the performance at every stage starting from circuit design, prototype fabrication, initial batch production, field trials, etc. The greatest degree of discipline, as well as patience, on the part of both engineers and users is called for to immediately stop the development cycle at any stage, whenever any deficiencies are noticed either in performance, reliability, or economic viability of the system if and when it goes on the production line. Postponing a problem, however small, to a later stage is not only costly but could many times become a deciding factor between the success or failure of a complex development project such as a wide-band microwave system.

The paragraphs which follow describe the development of the new generation of microwave systems in which the above criteria have been adopted in the best possible manner consistent with the resources available. While one can be more hopeful of success, the viability and the authenticity of the checks and balances adopted now will be fully established only when the new systems see actual usage in the near future.

III. THE NEW GENERATION

While the first generation of indigenously developed microwave systems was being put through its paces, the need for microwave systems in India was growing extremely rapidly and the Indian P&T and other users like Railways and Defence Services were constrained to go in once again for fairly large-scale import of microwave, satellite earth station, and troposcatter systems. This apparent reversion of "self-reliance" policy was quite justified by the network requirements and once again served as a serious challenge to the local industry to come up with much more serious effort in developing a new generation of microwave systems. Results of this effort to date have been encouraging, although it would be wrong and premature to claim that the systems which have now been developed will have no field problems whatsoever. However, as highlighted above, these systems are being taken through several rigorous intermediate evaluations and will have to definitely qualify through a host of "screens" before they can claim to have met the rigorous objectives of the communication networks.

Demand Pattern of Microwave and Allied Systems in 1970's and Beyond

Around 1971-1972, an assessment was made of the demand pattern for microwave and related systems in the next decade and beyond. The broad-band network being planned by the Indian P&T and the neighboring countries called for substantial quantities of 4- and 6-GHz 1800-channel systems with TV relay capabilities. The spur routes on the same network required systems with channel capacities up to 300 channels. In addition, the Railway network required dedicated systems up to 120 voice channels to link the various railroad stations for instant control and operation. The Defence Services called for specialized systems both in the line of sight (LOS) and troposcatter field with proven reliability and capability of working under severe "tactical" environments. Finally, the impact of satellite communication was being increasingly felt both in the international and the domestic field. Considerable effort was therefore called for in developing satellite earth station equipment which was akin to microwave systems.

The above requirements were carefully assessed and it was apparent that a large degree of overlapping design and manufacturing effort was called for, provided the various systems were to the same "technological level." This called for an R&D effort which was many times larger than any done hitherto in India. Under a major policy decision, accordingly, ITI launched a massive R&D program in close association with the users, towards the end of 1972. The clear and unequivocal directive to the R&D teams was that the end products had to meet the rigorous specifications of the users without any relaxations. The system should provide for smooth production as well as maintenance. Most important, however, was the stipulation that the systems would have to qualify through a series of rigorous evaluations before any major production or utilizatiou was begun.

Principal R&D Decisions

To achieve the goals above, certain basic decisions with regard to the mechanical configuration and the technological choice of critical subsystems and modules had to be arrived at quickly but judiciously. Some of these decisions are summarized below.

1) Mechanical practice: As the development of all the systems was being done on a concurrent basis, it was very desirable to have a common construction practice for all the systems. The earlier systems of ITI had followed the practice CP5, broadly based around racks which were 225 mm deep, 609 mm wide, and nearly 2743 mm high. Each rack was individually tailored for a particular system and the shelves were integrally mounted in this rack, along with the system wiring, before the rack was shipped to the site. This practice was developed for a situation where either a single transreceiver or, say, a complete supergroup of multiplex equipment occupied the complete rack. Thus from the customer's point of view, the basic building block of telecommunication equipment was the 600-mm wide rack. With the experience of utilizing these racks for the earlier generation of microwave systems, it was realized that in order to obtain higher packing density than a single RF transreceiver per rack, this practice would need radical modifications principally due to the need for combining a number of transreceivers in the same given vertical space. After a survey of the varous practices being evolved around the world, it was found that the vertical practice which originated in Germany, and since then had been adopted by most of the European manufacturers, had the maximum flexibility as well as mounting density microwave systems. Accordingly, the basic module of the system was made a 121 mm wide column up to 2.6 m high. The depth of the column was retained as before, namely 225 mm. Within the column, jack-in types of subracks housing plug-in units were developed. Incidentally, these subracks and the units are identical to those which had been concurrently designed for a horizontal shelf type construction for the multiplex and associated equipment of the new generation. This new practice, CP7M, has proved its versality and flexibility, as practically the entire range of microwave and tropo systems, which were the objectives of this development program can be accommodated in this practice. The mechanical parts utilized in this practice are far more economical than in the earlier

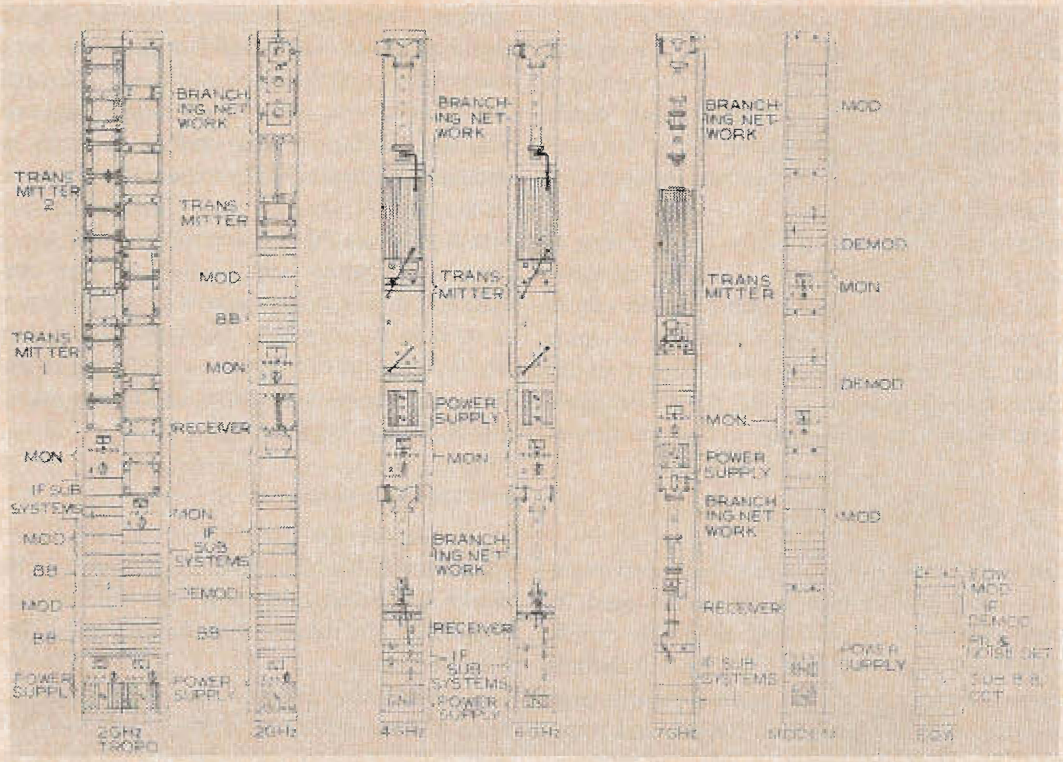


Fig. 3. Mechanical configuration of the family of microwave systems.

practice. Above all, the practice provides a high degree of flexibility in station planning and growth potential both at terminals and repeaters. Fig. 3 shows the systems in their mechanical configuration. As can be seen, except for the troposcatter system, all other transreceivers from 2 to 7 GHz have almost identical mechanical configurations as well as appearance [6].

2) Microwave frequency generation: The next major decision with regard to the family of systems was with respect to the type of microwave local oscillators. This choice was accorded very high importance in view of the extremely difficult last-minute upgradation of the earlier generation of local oscillators in the field after a fairly large batch of production. The straight multiplier chains which were the basis of the earlier generation of systems had proved to be expensive and difficult to adjust on the production line, and had fallen short of stability and noise specifications. Around the time the development program began in 1973, the new generation of microwave phase-lock oscillators, based on 1- or 2-GHz VCO's followed by single- or two-stage mulitpliers, became available as standard commercial items. These had originally been developed for retrofitting klystrons in the old generation of microwave systems, mainly in the U.S.A. After extensive evaluation, it was decided that, pending the development and reliability evaluation of ITI's own local oscillators sources, the local oscillators for all the systems would be procured from established vendors. This has proved to be a sound decision as it has substantially reduced the development time cycle and has also made the system designers' job of meeting noise specifications far easier.

3) Microwave power amplifier: The second subsystem which required an almost fundamental decision was the output power amplifier, particularly for the heterodyne systems and more so in the wider band capacities. At the time of choice of this subsystem, a few manufacturers had announced availability of fully solid-state 1 to 5 W heterodyne systems. Simultaneously, the technology of TWT's had received a very big boost due to the efforts put in by the manufacturers for space applications. Thus, the dc to RF efficiencies of the new tubes had jumped from a typical 8 percent to as high as 25 percent. Concurrently, the techniques for the high-voltage power supplies for the TWT's had also benefitted to a very large extent from the availability of high-frequency high-power semiconductors and the establishment of switching mode regulators and inverters. After preliminary evaluations, it was evident that the TWT's held a distinct edge as they could provide higher output power (at least by a factor of two) and at the same time consume anywhere up to half to one third of the dc power compared to the best available solid-state amplifiers. With the system objective of mounting a number of transreceivers side by side and the experience of high ambient conditions in the unattended repeaters in the Indian conditions, the efficiency advantages of TWT's became almost an overriding criterion. Accordingly, the broad-band systems, namely the 4- and 6-GHz, have initially been built around packaged power amplifiers which have the TWT as well as power supply integrally mounted in one small unit occupying less than 500 mm of the standard vertical column. With a view to leaving provision for subsequent upgradation to fully solid-state systems, the mechanical and electric interfaces to the rest of the system are suitable for both tubes and the solid-state amplifiers of the near future. It is anticipated that changeover to solid-state systems would take place after about 2 years production with TWT packaged amplifiers. For narrow-band systems in 2-, 7-, and 8-GHz bands, however, there was no particular difficulty in providing solid-state amplifiers of the required power. These utilize transistors for 2 GHz and phase level techniques or IMPATT amps for 7- and 8-GHz bauds.

4) Bay power supplies: Another subsystem which has traditionally not received its due importance is the power supply module for microwave systems. The experience with the earlier systems had indicated that baseband noise from the high-frequency ripple in multiple dc voltages could significantly degrade the noise performance of the complete system. These ripples were normally traceable to dc-to-dc inverters required to generate multiple dc voltages as well as high voltages for microwave tubes. In order to eliminate these inverters it was decided to operate all subsystems from a single −20-V power bus. This −20-V voltage was derived through a common switching mode regulator which has been designed both for maximum efficiency and minimum RF interference either through conduction or through radiation. This new unit has been responsible to a very large extent for meeting the overall system noise objectives. Furthermore, all the RF transreceivers can accept any raw dc voltage from −30 to −70 V without any change of strap and without any material difference in efficiencies. An efficiency of more than 70 percent for this switching mode regulator has been achieved at all loads and input voltages.

In broad-band systems utilizing TWT's, it is still necessary to have the necessary high voltages. These have been developed through a high-efficiency dc-to-dc converter integrally mounted with the tube to prevent high-voltage hazards as well as to minimize unnecessary induction of noise voltages in other parts of the system.

5) IF subsystems: For heterodyne systems at the repeaters as well as terminals, a considerable portion of the microwave systems are at the IF frequency of 70 MHz. Accordingly, a common IF subsystem family has been developed which is suitable for all systems right from 120 to 1800 channels. The only module which is modified is the IF filter, to obtain the required bandwidth. The IF subsystems provide the necessary group delay equalizer for the system as well as to some extent compensating for the microwave feeders echos, etc.

6) "Hardware" components: The hardware components of each of the subsystems are a direct function of the frequency of operation and the power-handling capacity. To the extent possible, MIC, stripline, and coaxial devices have been utilized in all the systems. These have provided much broader bandwidth than the equivalent wave guide versions, apart from smaller size and weight. The hearts of the microwave systems are the UP and DOWN converters. These have been designed with the greatest care so as to provide the required system performance on a repetitive basis. The technique adopted has always been chosen in such a manner to meet the particular system requirement.

Individual Systems

With the above criteria, the "family" of microwave and allied systems has been developed in an unified manner. As the aim of this paper is primarily to highlight the development strategies, only a brief mention will now be made about individual systems. A much more "hardware" and "results" oriented paper has recently been published on the whole family [6], while details of individual systems as well as requirements are being published concurrently [7]-[9].

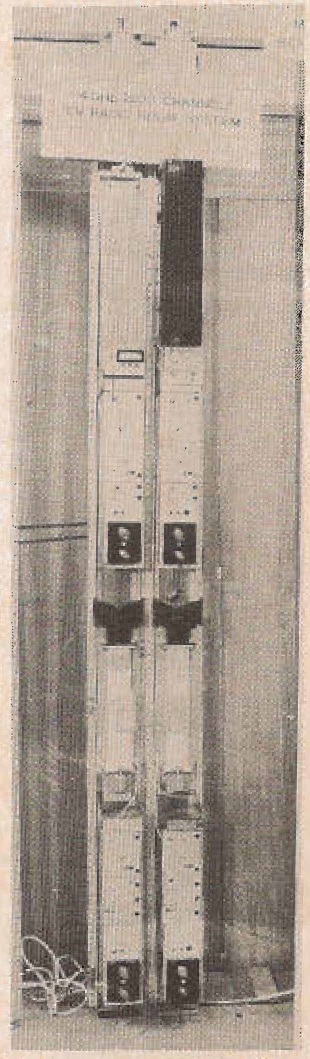


Fig. 4. 4-GHz 1800-channel transreceivers. The left column mounts one transreceiver with a TWT amp while the right column has a solid-state amp being evaluated as an alternative to TWT amps.

Two 4-GHz 1800-channel transreceivers are shown in Fig. 4. The lower portion of the column accommodates the complete receiver while transmitter is accommodated in the upper portion. The complete rack, 2.6 m high, accommodates the transreceiver as well as the corresponding branching equipments. Illustrations of systems in the other bands are shown in Figs. 5 and 6. It can be seen that the objective of a family approach has been achieved to such an extent that the systems are almost indistinguishable from one and another in terms of external appearance.

Performance Results

During the design process itself, each of the subsystems was allotted its individual share of the noise contribution. As soon as the system was complete, the overall performance was confirmed and it was encouraging to obtain systematic addition of such contributions—a factor which frequently

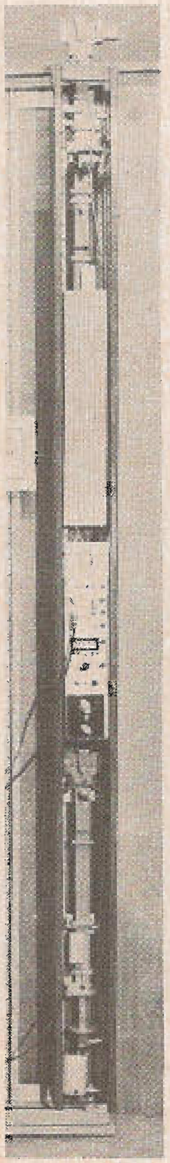
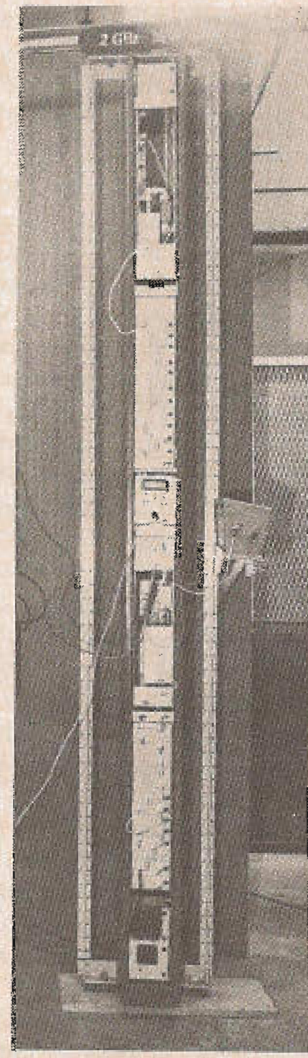


Fig. 5. 7-GHz all solid-state 300-channel heterodyne system.



(a)

(b)

Fig. 6. (a) 2-GHz all solid-state 120 channel heterodyne system. (b) Turn key microwave project for Uttar Pradesh Electricity Board, a 38-hop dedicated communication network in northern India being implemented with the 2-GHz system.

eludes the designers unless the interface points of the various subsystems have been properly chosen. The white noise performance of the four major members of the microwave family is shown in Fig. 7(a) and (b).

Related Systems

As indicated earlier, while the major exploitation of the microwave technology has been in the conventional LOS area, recent developments have substantially extended our "horizons." Notable examples are satellite communication and troposcatter systems. In both these areas, there have recently been substantial activities.

In spite of apparent system level differences, both these applications have substantial amounts of hardware in common with LOS systems. Accordingly, the above program has concurrently developed equipments to meet the satellite earth station as well as troposcatter requirements. A brief description of the results obtained for these areas is summarized below.

1) Satellite earth station equipment: India is one of the participants in the INTELSAT network. Around 1971, there was a requirement for a second earth station in addition to the one operating at Arvi near Bombay. The whole program had a definite time schedule and developing of the microwave ground control equipment (GCE) for both the up and down links was a very serious challenge to the group of engineers at

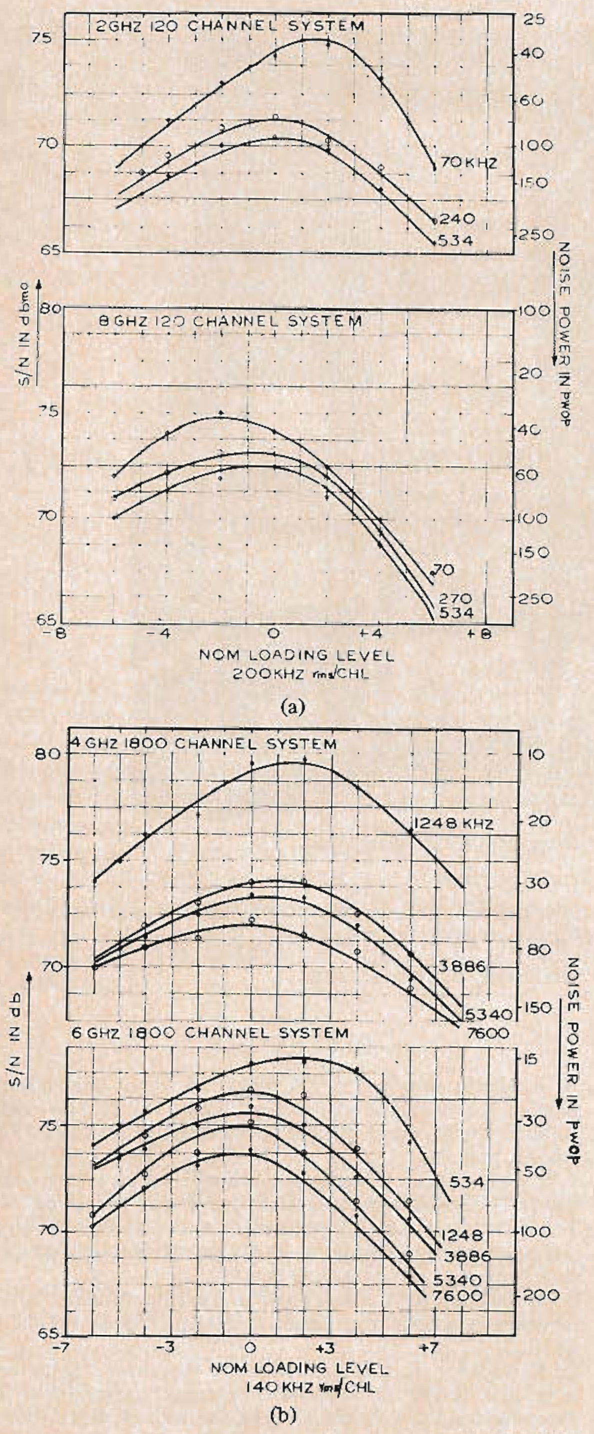


Fig. 7. (a) and (b) White noise performance of various systems.

ITI. Any slippage or slowdown in this program could seriously jeopardize the whole program of setting up a second INTELSAT standard earth station in India. Nevertheless, the challenge was worth taking and a definite commitment both in performance and time frame has been met for this project. The program has just been completed with slippage of only a few months in spite of several factors and stoppage of inputs both of which were beyond the control of development engineers. Fig. 8 shows the up and down link set, along with test results obtained on this equipment. As can be seen, the equipment is by no means miniaturized. However, this layout has been specifically developed to suit the maintenance philosophies of the users.

2) Troposcatter equipment: Traditionally, the troposcatter systems hardware has had limited similarity with the LOS equipment, in spite of similar techniques being applied in both the areas. This has been mostly due to the nonoverlapping markets as well as manufacturers for these two area. However, ITI development group was fortunate to be asked to enter this at about the same time when the development of the family of systems had taken strong roots. Accordingly, low-power (2-W output) portion of troposcatter equipment has been developed with the same system philosophy and mechanical layout as for the LOS systems. As shown in Fig. 9, the equipment bears remarkable similarity to the other members of the family of systems. In fact, this similarity extends to a large number of subsystems as well. The equipment as developed is probably the smallest size low-power tropo equipment available anywhere, and is also very competitive in cost.

IV. CONCLUSIONS

The development which began with modest support nearly 15 years ago has ultimately resulted in a reliable microwave product line in India. The group of engineers involved in this are quite conscious of the fact that the systems developed by them are by no means more advanced than those commercially available from developed countries in Japan, Europe, and the U.S.A. However, the effort has been made without any foreign support and with an industrial infrastructure which is several times inferior to that available in most of the developed countries. The development effort has not only led to several contemporary systems but has also encouraged a large number of small entrepreneurs in ancillary industries.

The above development effort highlights several important factors which are applicable whenever such major programs are to be implemented in developing countries. The primary factor, of course, is the need to place complete confidence in a selected group of domestic engineers and to give them adequate time and resources; above all, it is necessary to have considerable patience and restraint during the development process even when delays occur. It is well known that in the best circumstances, and even in the most advanced laboratories, large development programs of this nature do tend to slip. However, such slips are relatively easier to make up through, for example, "make buy" decisions in developed industrial infrastructures. On the other hand, working in a country like India, a change of even a simple imported component can lead to several months slippages thus upsetting the whole time schedule. Last, but not the least, the most important factor is the need to have extremely high self-discipline in ensuring quality and reliability of the equipment right from the feasibility stage and up to the induction stage. Developments of such nature have to be carried out in very close cooperation not only with the user but more importantly, with the agency responsible for ultimate production. In fact, due to the special difficulties in communication and transportation in developing countries, it is almost mandatory that such developments should be carried out next door to, or even under a common roof with, the manufacturing agency involved. In short, the responsibility of the designer should extend right up to the final acceptance of the product and its

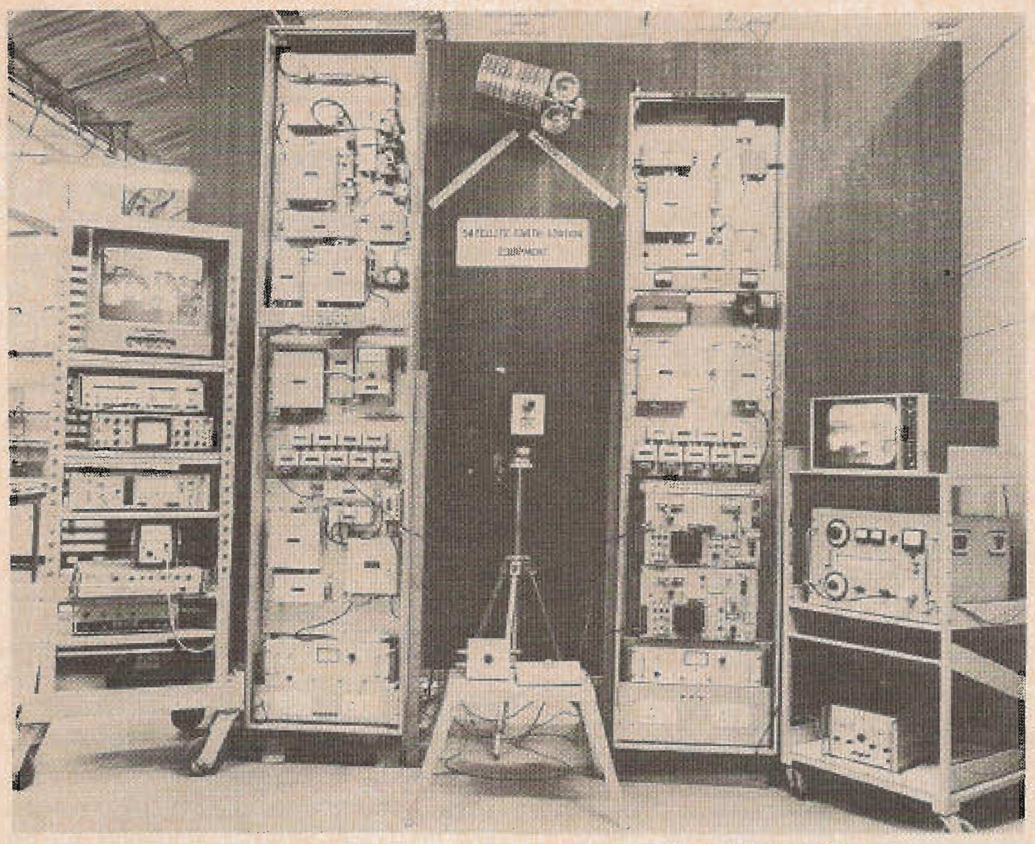


Fig. 8. Satellite earth station equipment under test on a simulated link.

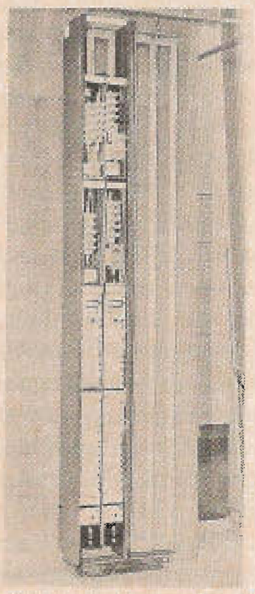


Fig. 9. 2-GHz troposcatter equipment. The left column accommodates two 2-W drivers, while the right column mounts two receivers in dual diversity. An additional column with two more receivers provides quad diversity.

usage in the field. Finally, the Indian experience has shown that even complex engineering projects can be accomplished in developing countries.

ACKNOWLEDGMENT

The paper has attempted to summarize the work of a large number of persons at different points in time during the 15-year period of microwave system development in India. The total number of persons who have contributed is too large to be individually acknowledged.

REFERENCES

[1] H. J. Mirchandani and V. M. Sundaram, "A 7 GHz microwave terminal for short haul application," *ITE J.*, vol. 11, Nov. 1965.

[2] D. K. Sachdev and H. P. Wagle, "IF amplifier circuits," *ITE J.*, vol. 11, Nov. 1965.

[3] T. S. Subramanian, "Microwave communication systems current trends," *Telecommunications* (Jabalpur, India), Dec. 1965.

[4] T. V. Srirangan *et al.*, "Development of 6 GHz 960 chl system," presented at the Seminar on Radio and Microwave Communication, University of Roorkee, Sept. 1971.

[5] D. K. Sachdev, A. K. Ghose, and D. Venkatasubbaiah, "A universal microwave solid state local oscillator," *ITE J.*, vol. 17, Feb. 1971.

[6] D. K. Sachdev, K. Sridhar, and B. V. Rajeswari, "Some aspects of a new family of microwave systems," presented at World Telecommunication Forum, Geneva, Switzerland, Oct. 1975.

[7] N. Krishnan Kutty, S. Mukherjee, and S. Vasanthakumar, "New 1800 channel/TV modem," to be published.

[8] A. K. Ghose and G. Jayadevappa, "7 GHz solid state microwave system," to be published.

[9] K. Nagaraj and V. Govindaraju, "2 GHz LOS/tropo microwave system," to be published.

★

Dharmendra K. Sachdev (A'58–SM'72) received a degree in electrical communication engineering from the Indian Institute of Science, Bangalore, India, in 1956.

After a brief sray at the National Physical Laboratory, New Delhi, India, where he worked in the field of low-frequency radio propagation, he joined the Indian Posts and Telegraphs Department (P&T) in 1958. A major portion of his service (1959–1970) in P&T was spent

at the Telecommunication Research Centre, New Delhi, where he made significant contributions in the first generation of open-wire, coaxial, and microwave communication systems. He has been with Indian Telephone Industries Ltd. (ITI), Bangalore, since January 1970. He has successfully expanded the company's R&D activities to take up a number of product-development programs in the fields of satellite earth station equipment, radio relay systems, wide-band coaxial systems, and a variety of digital systems such as ADM/PCM equipment, electronic PAX's, PABX's, etc. Since May 1971 he has been Chief Engineer, Transmission. He has also officially represented India in several foreign assignments. During 1969 he was a member of the Government of India Team at Hughes Aircraft Company, Los Angeles, CA, working to evolve a domestic satellite system for India. In 1971 he was a member of India's delegation to CCIR Joint Study Groups Meetings at Geneva for WARC (1971). He has also several times represented ITI abroad on various technical missions and negotiations.

Mr. Sachdev was the Chairman of the Bangalore Centre of the Institution of Electronics and Telecommunication Engineers during 1973–1975, and is a member of the Institution of Electrical Engineers, London, England.

Low-Power-Consumption Microwave Radio Relay System

TAKESHI KAWAHASHI, SENIOR MEMBER, IEEE, YUKIO KAITO,
HIROSHI TACHIZAWA, AND TADASHI FURUYA

Abstract—An economical microwave radio relay system in 2-GHz and 4-GHz bands for developing areas can be realized by the combination of extremely low-power-consumption radio equipment and static power supply equipment, such as thermoelectric generators, solar cells, etc. High reliability of this system minimizes the number of maintenance personnel and of routine inspection tours to economize the system operation cost. The system in the 4-GHz band is capable of transmitting up to 1800 telephone channels, yet it features outstanding economy in television or telephone channel transmission up to 960 channels, especially in remote areas. System description, comparison with a conventional system, and a brief radio equipment description are presented here.

I. INTRODUCTION

THE microwave radio system has come to be widely used throughout the whole world, including developing countries, by virtue of high reliability, high transmission quality, low initial installation cost, and short installation period.

The reliability of microwave equipment itself has been greatly improved in recent years by advances in semiconductor technology, as well as the careful and proper application of such devices. However, failure rates due to the power supply system have remained fairly constant and have been a major cause of the system failure. This is due mainly to the mechanical characteristics of the present power supplies. For example, engine generators are essentially rotary machines, while storage batteries and rectifiers of the floating system form a quite recommendable power system for dc operation. Therefore, overall system reliability depends mainly on the reliability of the power facility.

Recently, a number of novel and attractive power supplies, such as thermoelectric generators, solar cells, etc., without mechanical contacts or rotary parts, have appeared on the market for small-power-consumption requirements. Naturally, the combination of the extremely low-power-consumption equipment and the trouble-free, maintenance-free power supplies is preferable in order to improve overall system reliability and overall system economy.

This paper introduces this economical microwave communication system.

Manuscript received December 29, 1975.
The authors are with the Nippon Electric Company, Ltd., Yokohama 226, Japan.

II. SYSTEM FEATURES

The advantages of this microwave system are summarized as follows.

1) Since the power consumption is very low, a normal size floating battery system withstands the load for about one week, if there is an ac power failure at locations where commercial power is available. Thus there is no need for standby engine generators.

2) Even at a location where commercial power is unavailable, thermoelectric generators, or solar cells, or primary batteries can be easily and economically applied. There is no need for installation of two or three engine-generator sets, as is usually required.

3) Even at locations where the ambient temperature is extremely high, this equipment can be operated with sufficiently low ambient temperature in an underground shelter without air conditioning, because of low power consumption.

4) Branching, switching, dropping, or insertion of multiplex telephone signals at any repeater station are easy, because of the heterodyne type using 70 MHz IF.

5) Installation in inaccessible remote areas, like desert districts, mountainous areas, jungles, or isolated islands, is possible, because the equipment reliability is so high.

6) Substantial savings in maintenance cost for the overall system are realized.

7) Overall system reliability, including that of the power unit, has been considerably improved.

8) The number of skilled maintenance personnel required is reduced to a minimum.

III. SYSTEM CONFIGURATION

A. Radio Equipment

First, the power consumption of the radio equipment used for this system has been lowered to a significant extent. As shown in Fig. 1, the vacuum-tube-type transmitter–receiver consumed about 800 W per set. The solid-state TWT-type transmitter–receiver, developed at the early stage of semiconductor development, consumed approximately 250 W per set. The advanced version of the all-solid-state transmitter–receiver consumed about 100 W. However, power consumption of the new transmitter–receiver is reduced to a mere 10 W in 4-GHz equipment and to 6.5 W in 2-GHz equipment, in the case of 300-channel transmission, based on CCIR recommendations [1], [2], [4].

This power consumption reduction is made possible by a rapid advance in semiconductor technology. As a result, it has been possible to reduce the total power consumption of a through repeater station to a considerable extent.

Table I shows the power consumption of the through repeater station for various system configurations from 1 + 0 (one working channel + no standby channel) to 2 + 1 (two working channels + one standby channel). With the 1800-channel 2 + 1 system in 4 GHz, power consumption is as high as 303 W. However with the 300 channel or 960-channel 1 + 1 system, power consumption is only 43 W or 59 W, respectively. This significant reduction of the power consumption led to adoption of the new power supply system that will be discussed in the following paragraph.

The second major improvement made on the radio equipment is its reliability. As described below, a mean time between failure (MTBF) of 300 000 h or so can be secured for both the 2-GHz and 4-GHz equipment. This reliability improvement owes much to the rapid progress of semiconductor technology and optimum utilization of semiconductor devices. Fig. 2 shows one example of how the MTBF of the radio equipment, under adequate maintenance conditions, has been improved over the past 20 years. Accordingly, it is now possible to increase the standard maintenance interval of the radio equipment in proportion to improved MTBF.

Also, the low-power-consumption radio equipment permits replacing a whole transmitter subrack or receiver subrack with a new one, as well as permitting replacement of each individual function unit during troubleshooting. This point minimizes the number of personnel required for maintenance.

B. Power Supply

In areas where commercial power is not available, the dual diesel engine generator with alternative operation is employed in almost all cases. An example of analysis of the number of failures of a conventional microwave radio relay system using a diesel engine generator is shown in Fig. 3. In this example, data are based on one-year maintenance service of a system constructed by NEC. From this example, it is apparent that since 72 percent of the number of failures come from the failure of power equipment using rotary engine generators,

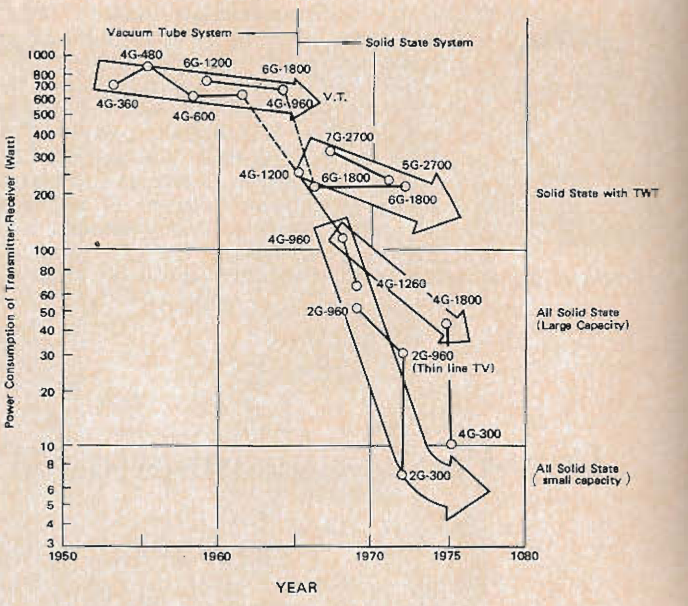


Fig. 1. Improvement of power consumption on microwave transmitter–receivers.

little improvement can be made on the failure rate of an overall system, no matter how substantially the MTBF of the radio equipment itself is improved. Also it is extremely time consuming to perform equipment maintenance service, since the engine generator contains mechanically moving parts, meaning that its MTBF is short and improvement of failure rate may be considered impossible.

This suggests and emphasizes a need for a more reliable new power supply system. The comparison of four types of power supply systems is shown qualitatively in Table II, and a comparison of the total cost (initial + running cost) is shown in Fig. 4. This comparison indicates that the first three of the following four types of power supply are the most advantageous for use as power supplies in through repeater stations, where commercial power is not available.

1) Thermoelectric generator: The thermoelectric generator is a purely stationary generator operating on the principles of heating one end of a thermocouple by a burner and cooling the other end by a heat radiation fin. Thermal efficiency is 220 W·h per pound of fuel, when propane gas is used, which is not so good; but a suitable unit with a maximum capacity of up to 100 W/unit is commercially available today. Experience shows that barring trouble with the fuel system, it offers reliability as high as 1 000 000 h in MTBF. The price of a 100-W unit, for example, is reasonably low. Two units of identical capacity may also be used for purposes of redundancy. However, it will be a standard practice to use a single set of this generator in combination with a floating battery.

2) Solar Cell: As long as solar radiation is available, the solar cell can generate power satisfactorily so that it is an ideal power supply system not requiring any fuel or any routine maintenance. As the amount of solar radiation becomes greater, the power consumption smaller, and the unit price of solar cell per watt lower, the total cost of power generation per year can be lower.

TABLE I
EXAMPLE OF POWER CONSUMPTION FOR A THROUGH REPEATER STATION

SYSTEM		2 GHz TX POWER	2 GHz ONE REPEATER STATION POWER CONSUMPTION	4 GHz TX POWER	4 GHz ONE REPEATER STATION POWER CONSUMPTION
TV + Sound (one way)	1 + 0	26 dBm	16 Watts	20 dBm	23 Watt
TP 300 CH	1 + 1	26 dBm	30 Watt	20 dBm	43 Watt
TP 960 CH	1 + 1	36 dBm	118 Watt	27 dBm	59 Watt
TP 960 CH + TV	2 + 1	36 dBm	175 Watt	27 dBm	87 Watt
TP 1800 + TV	2 + 1	———	———	37 dBm	303 Watt

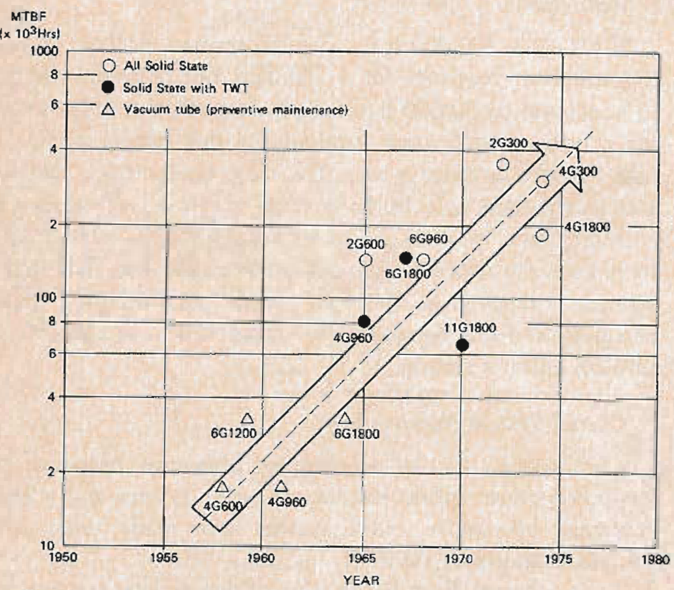


Fig. 2. MTBF of FM-heterodyne type transmitter-receiver.

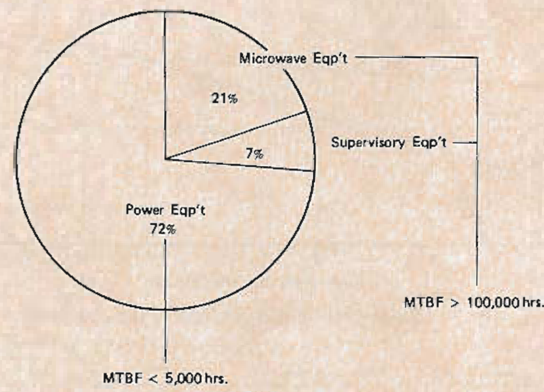


Fig. 3. Analysis of system failure of a conventional relay system.

In the Middle East, Africa, and Central Australia, where the average value of solar radiation per day is in excess of 500 cal/cm^2, the solar cell, whose current unit price is now about \$23.00 (U.S.) per watt, can be a competitive power supply system for a 43-W through repeater station. If the solar cell unit cost is substantially reduced in the years ahead, more widespread application of the solar cell can be expected. Fig. 5 shows the cost prediction of the silicon solar cell, though the unit price given may vary, depending upon the performance and quantity of solar cells purchased [3]. Should the unit price of the solar cell become one-tenth in 1980 of what it now costs, it can be considered as a highly economical and competitive power supply, even for the 430-W through repeater station.

Another problem besetting the solar cell is the difficulty in selection of a proper battery. With power generated from solar cells and stored in the floating battery on fine days, a continued supply of power can be assured on cloudy days or at night. It is important, therefore, to choose the capacity of the battery used on the basis of monthly solar radiation statistics, in order to realize an economical and reliable power system as a whole.

3) Primary Cell: The primary cell is a suitable power source for this system because of its maintenance-free and high-reliability advantages. The use of this cell entails much higher cost for the operation time involved, so that the primary cell is less advantageous than the aforementioned two types of power supply. However, the primary cell can often

TABLE II
COMPARATIVE ADVANTAGES AMONG NEW POWER SYSTEMS

	Maintenance Interval	Maintena-bility	Relia-bility	Initial Cost	Running Cost
Single Thermo-electric Generator with Floating Battery	1	2	2	2	2
Primary Cells	1	1	1	1	3
Dual Diesel Engine Generator for use on Charge-Discharge Basis	1	3	3	3	2
Solar cell system	1	1	1	3	1

Note: The numbers 1, 2, and 3 indicate superiority in that order.

quarters, ITT Corporation, Brussels, Belgium.

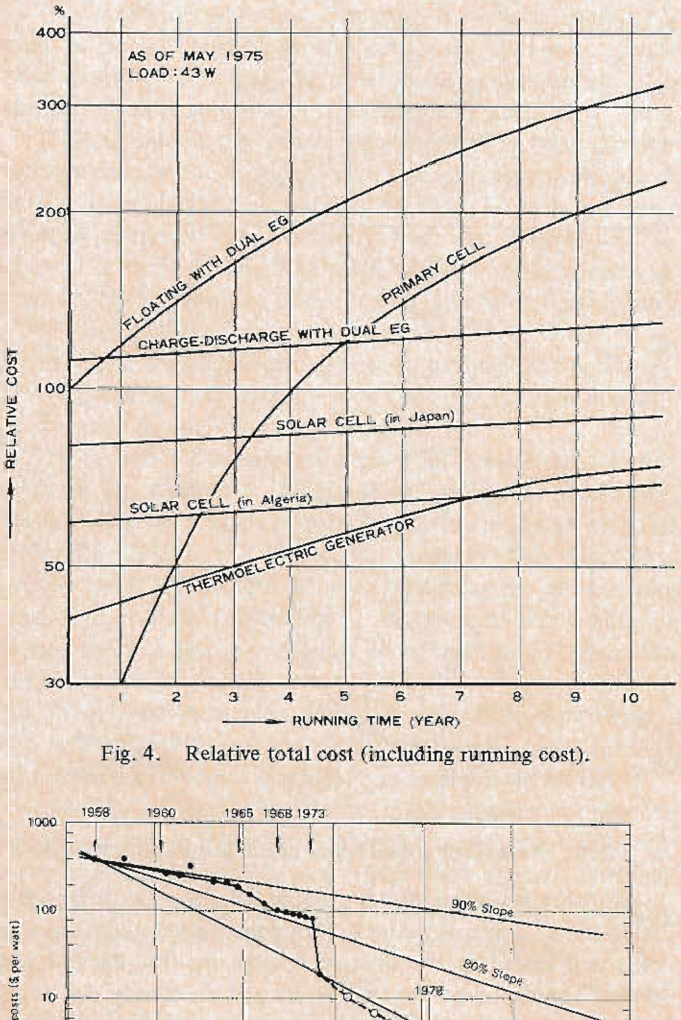


Fig. 4. Relative total cost (including running cost).

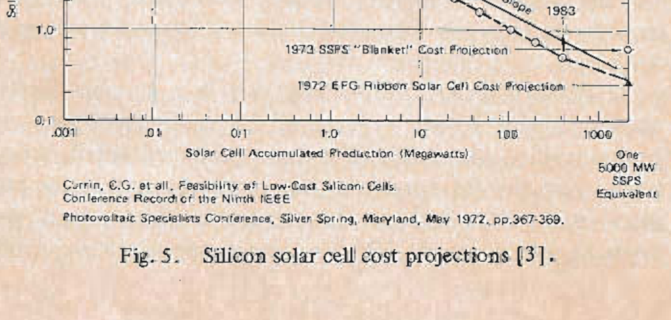


Fig. 5. Silicon solar cell cost projections [3].

be used as a temporary power source until such time as a commerical power source is made available.

The above three plans have been chosen as the most advantageous through repeater stations's power supply for the low-power-consumption microwave radio relay system. At the present stage of solar cell development, the solar cell proves to be particularly suitable for applications where there is much solar radiation and power consumption is relatively small. In other applications, the thermoelectric generator appears to be more suitable.

4) Floating Battery: In through repeater stations, where commercial power is available, a battery floating system (rectifier and floating battery) is most suitable because a certain capacity of the battery can feed coutinuously to the load for about a week, and no standby engine generator is required.

5) Aeronautical Warning Lights Consideration: For a tower taller than a certain height, the need arises to provide one or more warning lights. Warning lights often consume greater power than the radio equipment does. Therefore, in order to avoid excessive increase of power capacity due to provision of warning lights, it is important to determine tower height at an allowable minimum.

C. Maintenance

If MTBF is 300 000 h for one transmitter-receiver, that of 6 transmitter-receivers for a standard one-baseband section (6 hops) will be 50 000 h (=5.7 yr). Therefore, it follows that the routine maintenance required for this system will, as a rule, be once or twice a year. The radio equipment is replaceable in a subrack unit. In the eveut of a trouble, therefore, it is necessary only to check either the transmitter or receiver, and to replace the defective subrack with a new one. The failed subrack is repaired at the repair center. As a rule, no skilled personnel and test equipment are dispatched to an unattended through repeater station.

D. Overall System Improvement

Comparison of the economical advantage between the low-power-consumption microwave radio system and a conventional microwave radio system was made under the conditions shown in Table III.

As is apparent from Fig. 6, this system realizes a savings of up to approximately 80 percent in initial cost and approximately 60 percent in total cost (initial cost + maintenance cost for ten years), when compared to conventional systems.

E. Example of the System

This low-power-consumption system can also be used for applications in a system for television video signal drop or for drop and insertion of a maximum of a 300-channel telephone supergroup signal, at any through repeater station or diversity reception, etc. This system is highly flexible and versatile for such applications.

As one of the typical applications of this system for one-way television video and sound signals transmission, a system block diagram and a baseband signal frequency arrangement are shown in Fig. 7. In this system, a service channel signal is

TABLE III
COMPARATIVE CONDITIONS BETWEEN CONVENTIONAL AND LOW-POWER-CONSUMPTION SYSTEMS

System	:	Twin-path, TP 960 CH	
Distance	:	2, 500 km, 54 Hops (9 Baseband Sections each comprises 6 hops)	
Radio Equipment	:	Transmitter-Receiver, Modulator-Demodulator and Supervisory Equipment	
Radio Frequency Band	:	4 GHz Band (CCIR Rec. 382-2)	
Tower	:	50 m high, Guy Tower	
Power System	:	Conventional Type	
		Terminal -	Standby Engine Generator (30 KVA) with floating battery
		Repeater -	Dual Engine Generator (12.5 KVA) with floating battery
		Low Power Consumption Type	
		Terminal -	Standby Engine Generator (30 KVA) with floating battery
		Repeater -	Thermo Electric Generator with floating battery (60 watt x 2)

Note: Maintenance cost is subject to change by individual local conditions. The cost estimated here is based on that of a specific country.

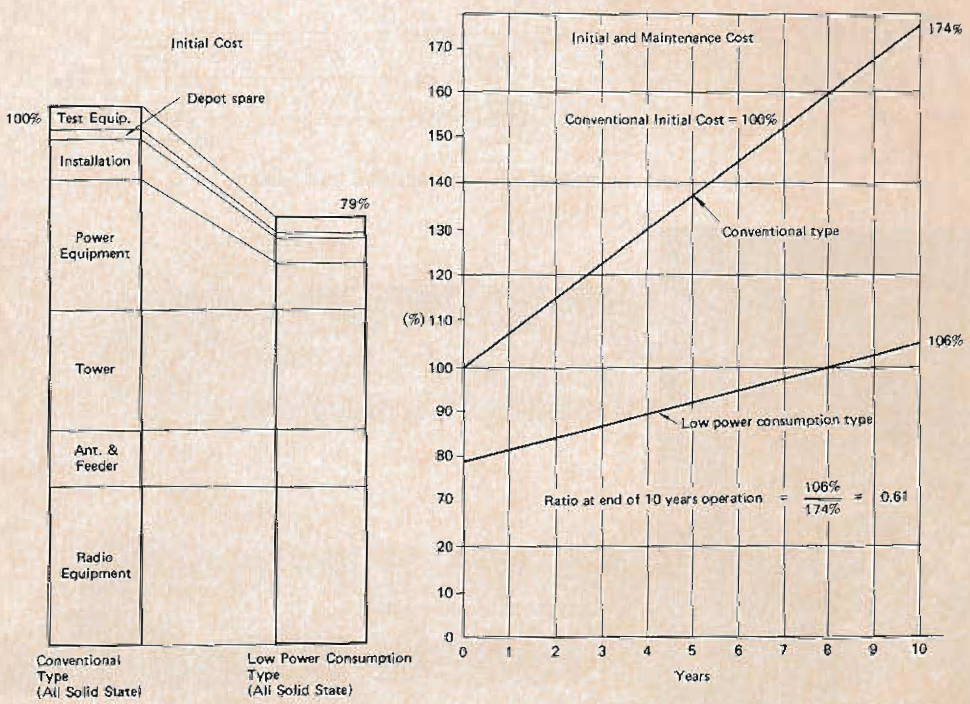


Fig. 6. Comparison of initial cost and maintenance cost between the conventional-type microwave radio system and the low-power-consumption type in the 4-GHz 960-channel system.

transmitted simultaneously with the television video signal, by one of the subcarriers, and the reverse direction service channel is transmitted with a separate RF channel provided exclusively for supervisory singal transmission. The total power consumption of this repeater station is only 16 W for the 2-GHz sysrem and 23 W for the 4-GHz system.

In Australia [1], a 2-GHz one-way television signal transmission system, identical to that illustrated in Fig. 7, was installed in a desert district. Here, a combination of rectifier and floating battery power supply system is adopted for stations where commercial power is available and a primary cell power supply system is adopted for stations where commerical power is not available. In such desert districts (where the ground surface is exposed to the direct sunlight and where the ambient temperature rises to an extreme high of some 60°C, in the summer time), an underground shelter is ideal for keeping the ambient temperature of the radio equipment at a moderate and adequate temperature range. Fig. 8 is a photograph of the underground shelter tested in Japan.

Another photograph showing the through repeater station, for transmissions of 300 telephone channels and occasional television, installed in Greenland, is shown in Fig. 9. A thermoelectric generator with standby primary cells was installed at each repeater station which consumes only about 30 W. Heat

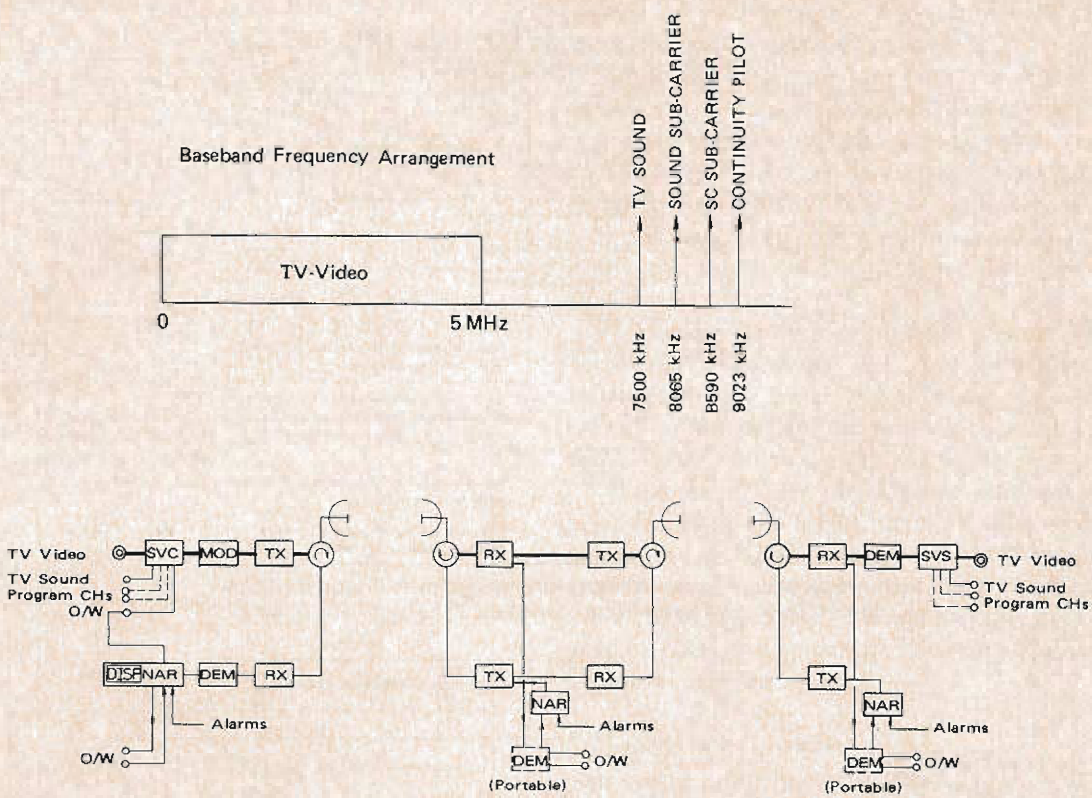


Fig. 7. An example of one-way television transmission.

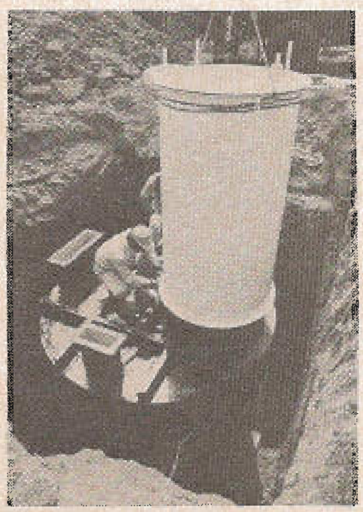


Fig. 8. Underground shelter installation.

Fig. 9. Naujagdlup Nuna repeater station (Greenland 2-GHz microwave radio relay system).

dissipation from the thermoelectric generator was utilized to heat the equipment room in the winter season. A prefabricated structure, transported by helicopter, was built on the ground at a repeater station site where no access road is available.

IV. LOW-POWER-CONSUMPTION MICROWAVE RADIO RELAY EQUIPMENT

A. 2-GHz/4-GHz Radio Equipment Performance

Table IV gives the major performance characteristics of the 2-GHz and 4-GHz microwave relay transmitter-receivers. The frequency bands of the transmitter-receiver cover the 2-GHz and 4-GHz bands of CCIR Recommendation 382-2. The 2-GHz transmitter-receiver is capable of 960-telephone-channel transmission or color television transmission with a sound channel. The 4-GHz-band transmitter-receiver is capable of up to 1800-telephone-channel transmission or color television transmission with 4 sound channels. As given in Table IV, transmitting output power can be increased up to 4 W for the 2-GHz equipment and up to 5 W for the 4-GHz equipment, merely by increasing the number of output amplifier stages according to the transmission capacity. The 4-GHz-band receiver is so designed that a microwave FET preamplifier can be added according to needs. 4.5 dB is the noise figure with the FET, which assures the 1800-channel transmission.

TABLE IV
2-GHZ AND 4-GHZ TRANSMITTER-RECEIVER PERFORMANCE CHARACTERISTICS

	2-GHz System	4-GHz System
FREQUENCY	1.7 ~ 2.3 GHz	3.4 ~ 4.2 GHz
TRANSMISSION CAPACITY	300 ~ 960 CH or Color TV + Sound-CH	300 ~ 1800 CH or Color TV + 4 Sound-CH
TRANSMITTER POWER	0.4W/1.6W/4W	0.1W/0.5W/1W/5W
RECEIVER NOISE FIGURE	6.5 dB	6.5 dB/4.5 dB
POWER CONSUMPTION	6.5W/13.2W/28.5W	10W/14W/19W/50W

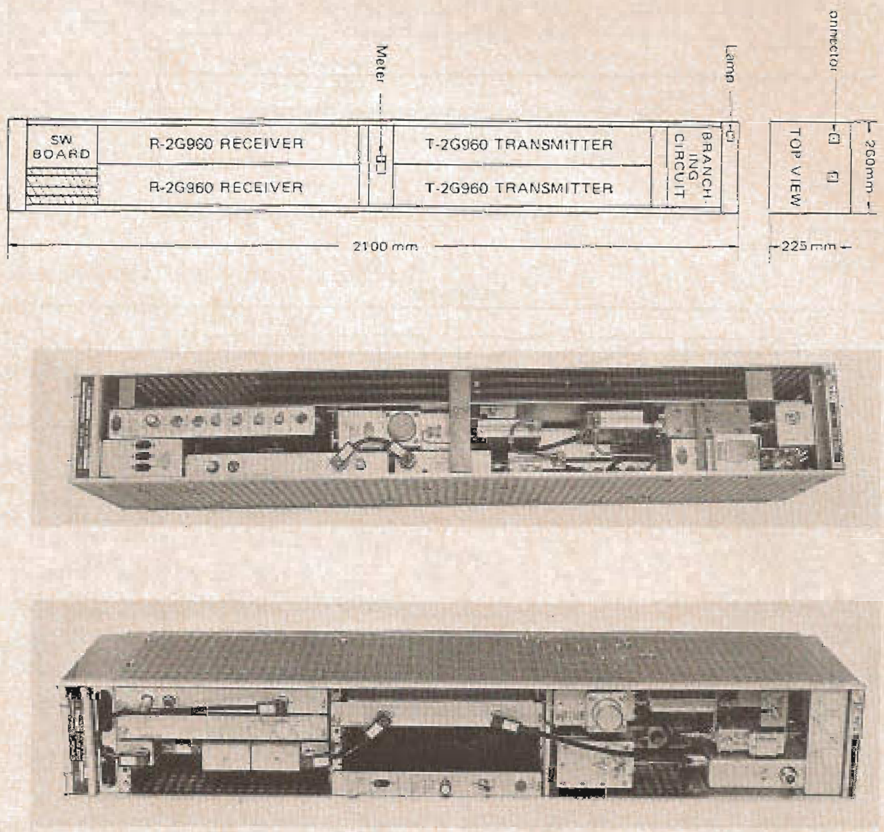


Fig. 10. Bay configuration with subrack-mounted transmitter unit and receiver unit of the TR-2G960 transmitter–receiver.

B. 2-GHz Transmitter–Receiver

As shown in Fig. 10, equipment, consisting of two sets of 112-mm-wide subrack-type transmitters and receivers is mounted on the bay. This subrack unit construction is designed with major emphasis placed on the ease of handling, installation, and maintenance, whereby access only to the front of the bay is needed. Each subrack unit is provided with a fault alarm indicator so that, in the event of trouble, repair of faulty equipment can be made simply by replacing the indicated defective subrack unit with a spare one.

Fig. 11 shows a block diagram of the 2-GHz transmitter. This transmitter is unique in that it uses a 2-GHz direct transistor oscillator as a local oscillator and a microwave high-gain injection-locked transistor amplifier.

The local oscillator of the 2-GHz transmitter is a self-oscillator using a super-invar cavity resonator. With this oscillator, the number of parts used can be minimized and a frequency stability of $\pm 5 \times 10^{-5}$ can be achieved at an output of +17 dBm. When the need arises for insertion of an order wire signal, supervisory signal, and telephone supergroup signals (300 channels, maximum) from a repeater station, the 2-GHz FM oscillator of the transmitter can be easily mounted in place of the local oscillator for such applications.

The injection-locked transistor amplifier comprises a 4-port

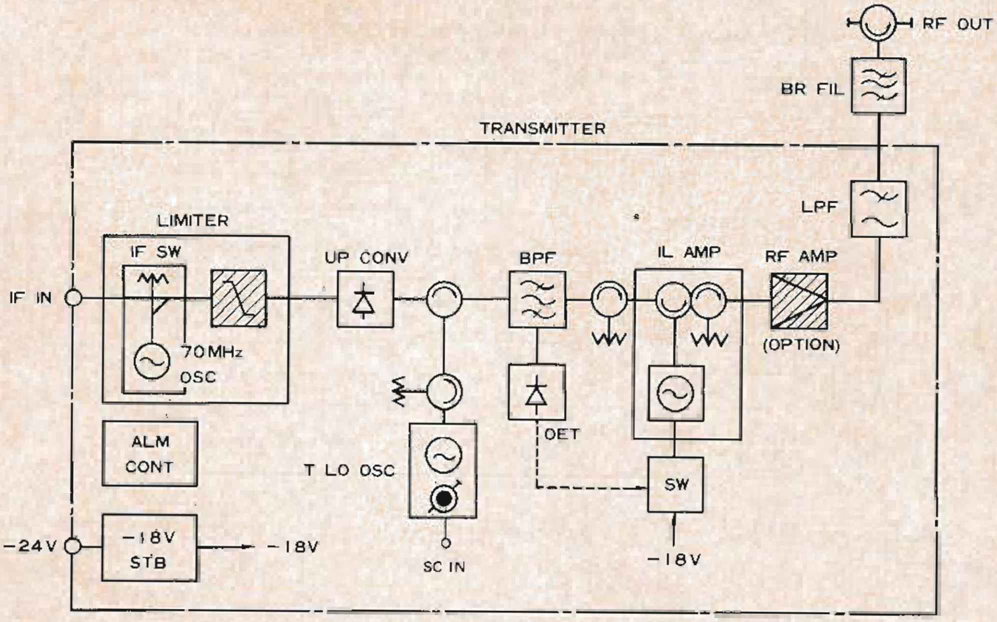


Fig. 11. 2-GHz transmitter block diagram.

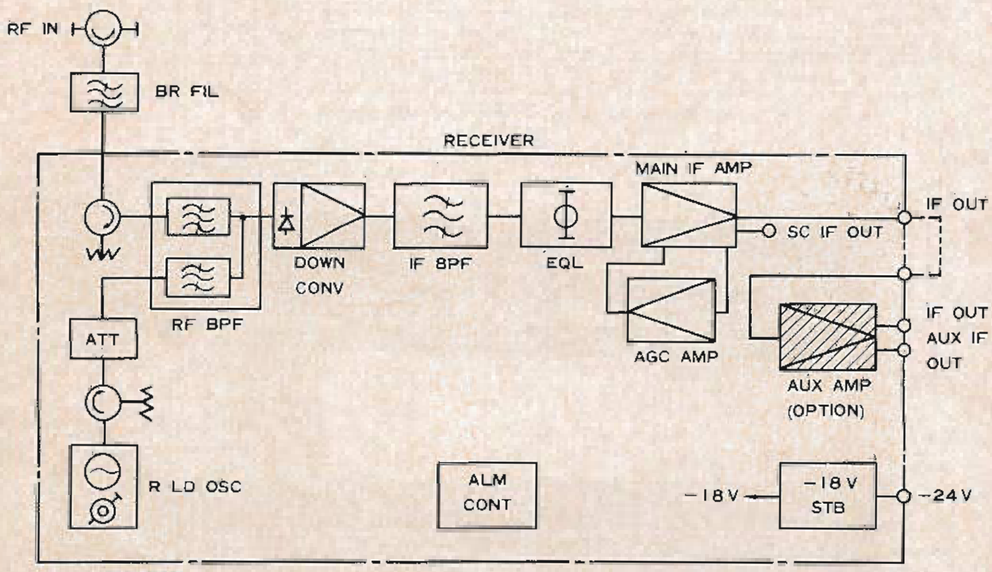


Fig. 12. 2-GHz receiver block diagram.

circulator and a 2-GHz transistor oscillator. The injection-locked amplifier also contains an alarm circuit [5], [6]. To prevent unwanted free-running oscillation of the injection-locked amplifier caused by an inadequately low or interrupted input level, the alarm circuit cuts off the power supply to the amplifier and, simultaneously, issues an alarm when the input level of the injection-locked amplifier is dropped by 6 dB or more from the standard level. Even when the power supply of the amplifier is cut off, amplifier gain is reduced to about unity and RF carrier transmission continues.

The total power consumed by the transmitter can be reduced to as low as 4 W with the injection-locked 0.4 W RF output transistor amplifier. The output power can be raised to either 1.6 W or 4 W using an additional wide-band class-C power amplifier which consists of microwave transistors and printed circuits.

Fig. 12 shows a block diagram of the 2-GHz receiver and Fig. 10 (at right) shows an outside view of the receiver subrack unit. Mechanically, this subrack unit is almost identical to the transmitter subrack unit. With a low-noise Schottky-barrier-diode-type mixer and a low-noise IF transistor, the overall receiver noise figure is 6.5 dB. The power consumption of this receiver is only 2.5 W or about one-fourth of a conventional receiver. This low power consumption has been realized by using a high-efficiency 2-GHz direct oscillator with a cavity resonator as a receiver local oscillator and a specially designed low-power-consumption-type IF amplifier circuit which is shown in Fig. 13. Here, the circuit feeding dc power to the

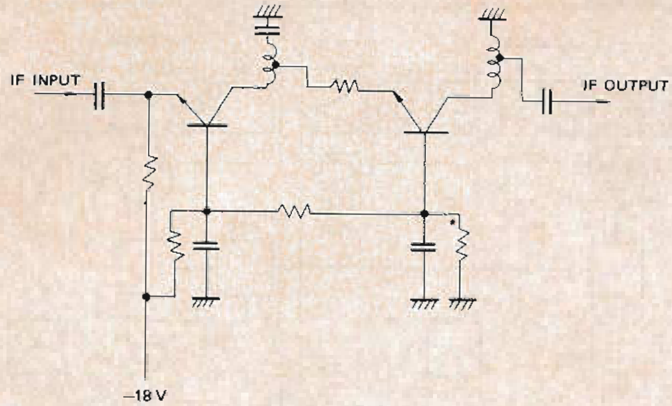


Fig. 13. A typical IF amplifier circuit diagram for the low-power-consumption-type receiver.

TABLE V
2-GHZ TRANSMITTER AND RECEIVER POWER CONSUMPTION

Power Consumption at −20 V DC	TX Output Power		
	0.4W	1.6W	4W
Transmitter (without limiter)	4.0 W	10.7 W	26.0 W
Receiver	2.5 W	2.5 W	2.5 W
Transmitter-Receiver	6.5 W	13.2 W	28.5 W

two stages of amplifiers is in series, thus forming a high-gain and low-power consuming IF amplifier.

The power consumptions of a 2-GHz transmitter and receiver for a repeater station are given in Table V as parameters of transmitter power.

C. 4-GHz Transmitter-Receiver

An external view of the 4-GHz transmitter–receiver is shown in Fig. 14. Two sets of compactly built subrack-type transmitters and receivers are mounted on the bay.

A block diagram of the 4-GHz transmitter–receiver is shown in Fig. 15. The basic technical approach to the low-power-consumption design of this equipment is the same as that to the 2-GHz equipment. Salient features of the 4-GHz transmitter–receiver include use of a negative-resistance-type high-gain amplifier for RF Amp 1 in the transmitter and the flexibility of permitting a change in the number of amplifier stages, according to the output power (0.1 W, 0.5 W, and 1 W). RF Amp 2 is a 5-W class-C high-efficiency transistor amplifier. Both RF Amp 1 and RF Amp 2 have sufficient broad-band characteristics for 1800-channel transmission applications.

As shown in Fig. 15, the receiver is unique in that an FET amplifier is used in the input end of the receiver section. Other design derails are substantially the same as those of the 2-GHz receiver. The FET amplifier is designed to have broad-band frequency characteristics for sufficient coverage of about a 500-MHz bandwidth with a gain of 11 dB.

The noise figure of this FET amplifier is only as low as 2.2 to 2.5 dB for a bandwidth of 500 MHz. By using this FET amplifier, the total noise figure of the receiver can be improved to 4.5 dB.

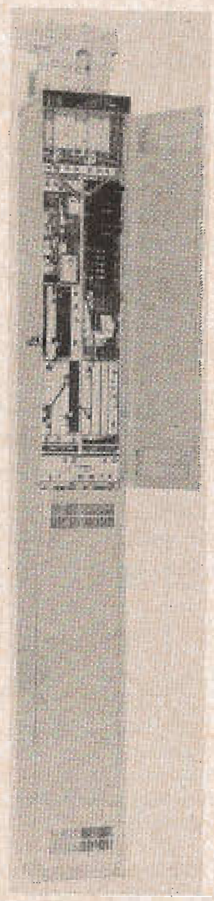


Fig. 14. Photograph of 4-GHz transmitter–receiver bay.

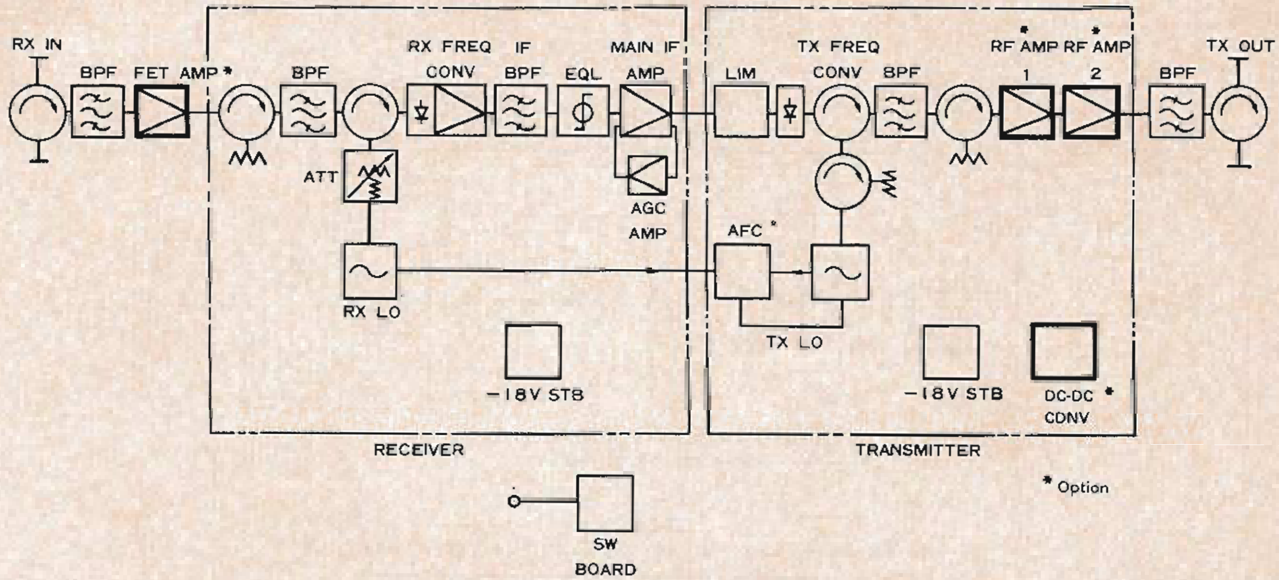


Fig. 15. 4-GHz transmitter–receiver block diagram.

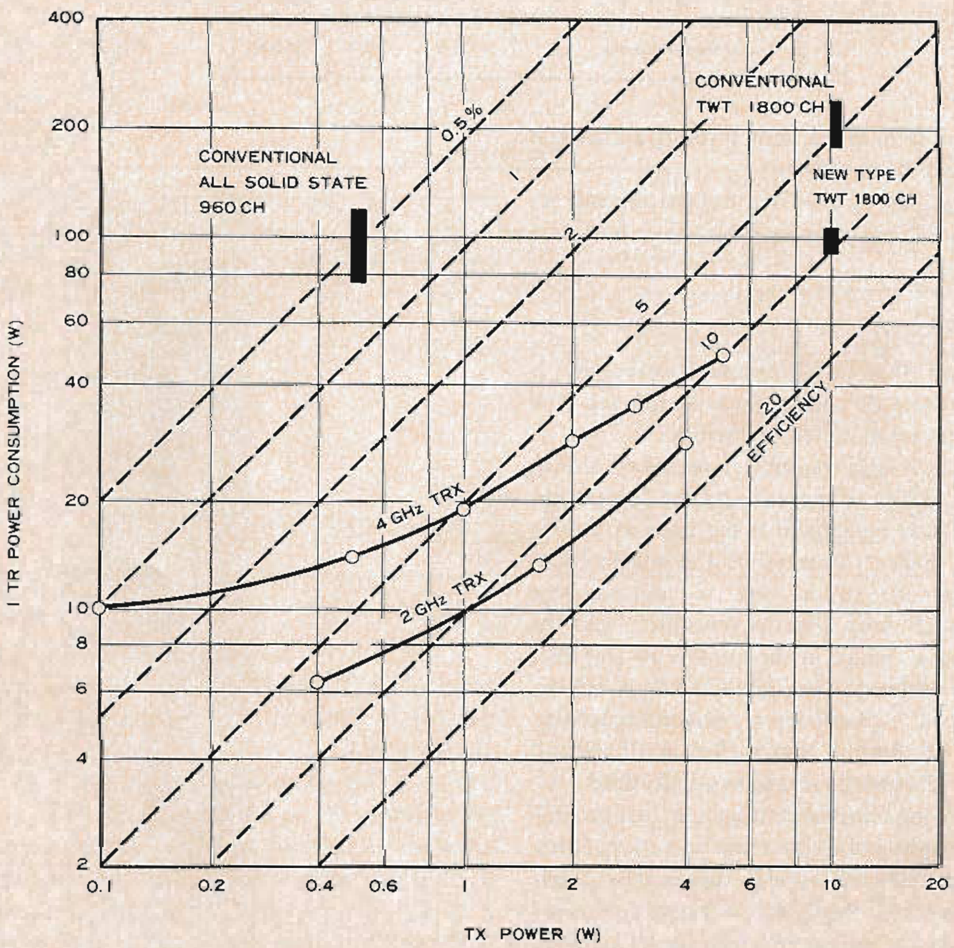


Fig. 16. Relationship between power consumption and transmitter power.

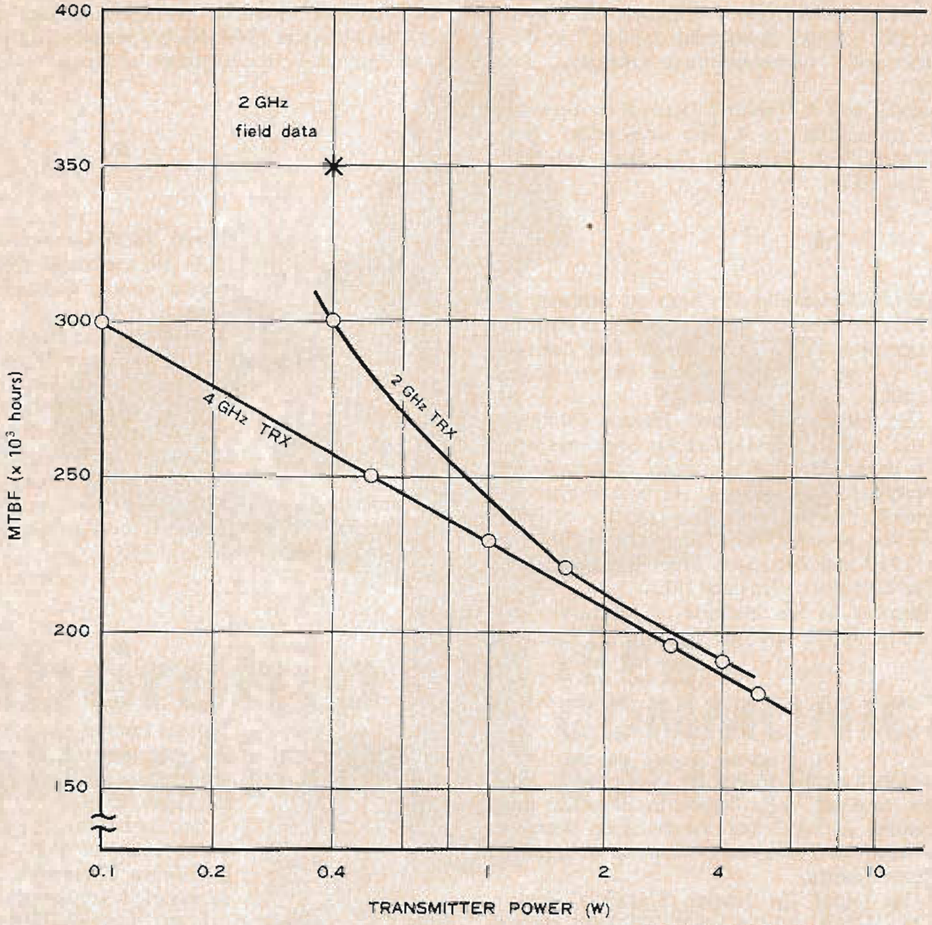


Fig. 17. Estimated 2-GHz and 4-GHz transmitter–receiver MTBF and field data.

D. Power Consumption and MTBF

Relationship between the power consumption of the transmitter–receiver and the transmitter power is shown in Fig. 16. Conventional 960-channel all-solid-state radio equipment and conventional TWT-type 1800-channel radio equipment are also shown. Here it is apparent that the power consumption of the new 4-GHz radio transmitter–receiver is reduced to less than one-seventh of that of a conventional all-solid-state radio transmitter–receiver. It can be reduced to one-fourth of that of a conventional TWT-type radio transmitter–receiver.

Fig. 17 shows the estimated MTBF of the 4-GHz and 2-GHz transmitter–receivers as parameters of the transmitter power. The point marked with an asterisk denotes the actual MTBF obtained from two years of operation in Greenland. From this actual data, it is expected that the new 4-GHz equipment may have an actual MTBF of as much as 300 000 h.

V. CONCLUSIONS

With the advent of these extremely low-power-consumption high-reliability microwave communication systems, the application of microwave communication systems will be expanded to areas previously considered impossible. It is ardently hoped that these systems will contribute greatly towards the improvement of telecommunication in many developing countries. It is also hoped that these systems will be installed widely as one of the new standards of the microwave communication system of today and tommorow. It is indeed a great pleasure to be able to introduce this paper to those who are dedicated to the planning, development, and service of microwave communications.

ACKNOWLEDGMENT

The authors wish to thank the responsible members of the Central Research Laboratories and Semiconductor Division, NEC, for developing the new microwave transistors, diodes, etc. The authors also express their appreciation for the valuable encouragement and guidance of Telecom Australia and the Greenland Technical Organization.

REFERENCES

[1] L. D. Sebire, "The provision of television services in remote area," *Inst. Radio Electron. Eng. Australia*, pp. 52–58, Mar. 1975.
[2] H. Tachizawa, K. Kinoshita, and H. Tsuburaya, "Low power consumption microwave radio system," World Telecommunication Forum, Geneva, Oct. 1975, parallel tech. sessions 3.2.4.
[3] P. E. Glaser, "The satellite solar power station, a focus for future space activities," Arthur D. Little presentation to the U.S. House of Representatives, July 22, 1975.
[4] K. Kinoshita, "Low power consuming 4 GHz 960-channel transmitter–receiver," IREE Int. Electron. Convention G-5067, Australia, August 1975.

INFORMATION FOR AUTHORS

TECHNICAL MATERIAL for publication in the IEEE Transactions on Communications is invited. Submitted material must be within the scope of interest of the IEEE Communications Society as defined on the inside front cover. IEEE Transactions on Communications does not print material previously copyrighted, published, or pending publication elsewhere, except for items that may have had limited distribution or that have been printed in abstract form only. Papers published in Convention Records or Digests are common exceptions. Unless specifically stated otherwise in the letter of submittal, manuscripts will be assumed to comply with these requirements. The fact that a paper may have been presented before a meeting sponsored by the IEEE Communications Society does not ensure its acceptance for publication in the IEEE Transactions on Communications, the essential requirements for presentation and publication not being identical. All papers are considered for publication on the basis of their individual merit alone.

Editorially and typographically, the format of the IEEE Transactions on Communications follows that of Proceedings of the IEEE. Papers should be written concisely and be no more than 20 double-spaced typewritten pages, keeping to a minimum all introductory and historical material. It is seldom necessary to reproduce in their entirety previously publisbed derivations where a statement of results, with adequate references, will suffice. In preparing mannscripts, standard practice should be followed with regard to headings, footnotes, abbreviations, equations and symbols. Authors must provide illustrations suitable for reproduction without redrawing or retouching; drawings must be made with India ink on drafting cloth or white drawing paper. For further instructions, see "Information for IEEE Authors," available on request from the IEEE Editorial Department, 345 East 47 Street, New York, NY 10017. It is essential that each snbmitted manuscript be accompanied by a 75- to 200-word abstract clearly outlining the scope of the paper. The abstract may also be used in preparing library card information. All papers should have company clearance before submission. Papers submitted for review are assumed to have no proprietary material for which appropriate patent coverage bas not been applied for. Responsibility for any proprietary material submitted rests solely with the autbor and his organization, and is in no way the responsibility of the IEEE or its editorial staff.

Five copies each of the abstract, the manuscript text, and the illustrations (but not the original illustrations themselves) should be submitted for consideration to the Director of Publications. Manuscripts may also be submitted directly to the listed Editorial Board member responsible for a particular field of interest. All submissions are reviewed by members of the appropriate Technical Committee who will recommend acceptance, modification, or unacceptability of the material for Transactions publication. All unused items will be returned to the authors. Supplementary materials, such as biographies and original illustrations, will be requested when needed for publication.

Papers which were previously presented before a conference or symposium should be so identified. A paper not presented orally earlier may be considered as a candidate for such by a Technical Committee, and the author may be invited to give such presentation. The inclusion of conference discussion and response to questions or suggestions from a symposium audience can considerably improve a paper when subsequently published.

The Editor also invites a) letters and discussion on papers printed earlier; and b) other brief items for publication in the Concise Papers and Correspondence seetions, respectively, of this Transactions. An abstract of about 50 words or less is required to accompany each Concise Paper and Correspondence for information-retrieval purposes. Concise Papers are to be limited to 10 double-spaced typewritten pages.

PAPERS SCHEDULED TO BE PUBLISHED IN THE NEXT ISSUE

August 1976