which shows only the peak heating factors from Fig. 3. The strong dependence of $\bar{H}$ on Reynolds number suggests that the interference may be tripping the boundary layer to turbulent flow. The data of Fig. 3 are also plotted in Fig. 4b in terms of the ratio of the measured peak interference heating to a reference turbulent value, $\bar{H}_T$. The reference turbulent value is taken as the turbulent heat-transfer coefficient calculated at the sonic point of a scaled 1-ft radius sphere. The interference heating data when referenced to a turbulent value are essentially independent of Reynolds number. This is a strong indication that the primary effect of interference in the present tests was to cause transition to fully developed turbulent flow, and emphasizes the necessity of checking all interference data for transitional effects.

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A Study of Satellite Television Broadcasting Systems for India

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Introduction

BROADCASTING of television signals to cover large areas appears to be feasible through the use of high-power transponders and large antennas mounted on geostationary satellites. These satellite systems appear to be very important, particularly for the new, developing, and large countries because they provide a base for education and information dissemination to achieve rapid national development. The first test of direct satellite broadcast of television is planned to be tried out in India during 1974 using a NASA launched ATS-F satellite. During this experiment the cities, large and small, would be provided TV reception through receive-transmit terminals, the villages and the remote and inaccessible areas through direct reception. Principles of operation with respect to receive-transmit terminals is fairly well established, whereas the problems relating to direct reception from satellites in the hostile environmental conditions of remote and inaccessible villages are yet to be solved. In addition, from considerations of interference to existing terrestrial systems, various technical constraints have been imposed on the mode of satellite TV transmission, type of reception and other parameters. Because of the technical and environmental constraints, the conventional TV receiver in its regular form is unsuitable for direct reception of satellite signals. Therefore, what is required is an augmented receiver which would meet all the technical specifications as well as operate efficiently in remote areas.

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Satellite Instructional Television Experiment

As a first step to the use of television for a large area coverage in a short period of time, and based on the joint study groups recommendations,[1] the Department of Atomic Energy (India) entered into an agreement with NASA to conduct a joint satellite television experiment using the ATS-F satellite to be launched by NASA around 1973.

The space segment of this system would consist of the ATS-F satellite positioned within effective operational view of India, for the purpose of this experiment, in synchronous equatorial orbit, with a 30-ft parabolic antenna pointed generally toward the center of India with an accuracy of $\pm 0.1°$. A FM transmitter operating in the 800–900 MHz frequency range, with a rf bandwidth of approximately 30 MHz, will provide adequate power (80 w) for transmitting TV program material and two audio channels to augmented conventional TV recievers. In this experiment the up-link transmission to the ATS-F satellite would be in the 6 GHz band. The Experimental Satellite Communication Earth Station (ESCES) at Ahmedabad will be used for transmitting Indian ITV program material to the satellite and for monitoring these transmissions and performance of the satellite during the duration of the experiment. Augmented conventional TV receivers would be capable of receiving monochrome TV transmission from the satellite and one of the two audio channels transmitted. For this purpose the conventional receivers would be augmented by a front-end, viz a small parabolic receiving antenna (7–10 ft in diameter) and a preamplifier FM to AM converter of sufficient quality, to receive transmisssions from the satellite. In high village density areas, transmission from the satellite could be received by cheap "mini earth stations" for rediffusion by VHF TV transmitters to conventional TV receivers located in nearby villages. A receive only facility, using a 20–30 ft parabolic antenna is required near the VHF TV transmitter. The experiment envisages the test of a hybrid system involving both direct reception by augmented TV receivers as well as rebroadcast to conventional TV receivers. About 2000 direct reception sets and 3000 conventional sets will be located in 5000 villages. The direct reception sets will be located in clusters of about 400 sets each in various parts of the country, while the conventional sets will be located in villages around the existing and planned terrestrial TV transmitters in the larger cities. The TV sets will be located in different cultural, linguistic, socio-economic, and environmental regions of India. This will provide the wide range of experience which is so necessary before a diverse country like India can embark on a large nationwide hybrid TV system. This experiment will provide invaluable experience for setting up an ongoing operational system. The full responsibility for the TV programs and the ground segment hardware will be that of India, and this includes the task of developing the required hardware also.

Operational Environment

To test out the concepts of community reception in villages, India provides an excellent experimental situation. It has almost all types of environmental conditions. Therefore, the community receivers should be designed to operate in all these conditions. The climates and physical environments that must be endured by these receivers are severe. The range of these environments extend from the extreme cold of winter in the mountainous northern part of India, to the torrid summer in the southern area. The large shore lines will require humidity and salt protection and the dry plains will need dust protection. Another extreme is the dampness and protection measures are necessitated by the months-long monsoons.

The other major environment is the potential shock and vibration that may be encountered in transporting the sets over the rough roads leading to many of the villages. Partial protection might be supplied by suitably padded transport containers, but the receivers must be capable of withstanding a physical handling environment that may be far worse than normal household receivers are capable of withstanding.

An additional requirement is imposed by the fact that about 80% of the 560,000 villages in the country are unelectrified. Thus, if TV is to have meaningful impact by covering the rural areas, than it is necessary to think in terms of low-power consumption sets which can be operated from batteries in unelectrified villages. The problem is further complicated by the necessity of having large screen-size sets, for, in India—as in all developing countries—TV can reach the masses only through community sets which can be viewed simultaneously by 50 or 100 persons.

Community Television Set

The community TV receiver consists of a front-end electronics attachment and a conventional TV receiver. The front-end attachment is required because the downlink signals are in the UHF band and frequency modulated. Therefore, they have to be converted into a suitable signal for use directly in the conventional receiver. Studies conducted on the type of receiver for community viewing have resulted in recommending a sold state receiver fully ruggedized with low power consumption. The ruggedization will increase the set cost marginally but has the potential of saving a far larger sum by reducing the maintenance and extending set life. A summary of the receiver characteristics is given in Table 1.

The most significant characteristics of the community receiver needed for direct satellite broadcasting to the villages are its cost and the impact of its performance on the cost of other equipment. There appear to be four major types of requirements which will constrain the community receiver design. These are technical performance fabrication techniques, the physical environment and the operating situations. In order to evaluate an optimum design approach from the considerations, four approaches appear to be feasible for the community TV set. These approaches are 1) direct reception of TV signals only, by the community receiver; 2) direct reception of the satellite signals as well as the signals from the terrestrial redifiusion transmitter; 3) direct reception of the terrestrial signals and reception of satellite signals by means of an external converter; and 4) direct reception of the satellite signals by the receiver and a subsequent distribution in the village to additional TV sets.

A study conducted on the community receiver on the above possibilities with respect to various technical and environmental parameters indicated that a) the design should be based on solid state devices to restrict the power consumption; and b) the functions of the frequency and modulation conversions would be integrated with the rest of the functions of the TV set resulting in cost savings as well as contributing to the minimization of failures.

Table 1 Summary of receiver characteristics

Frequency range	790–890 MHz
Modulation (video & audio)	FM
Noise figure	6 db
Bandwidth per channel	30 MHz
Applicable standards	CCIR-B
Number of video channels	Select 1
Number of audio channels	Select 1 from 2
Prime power dissipation	50 watts
Screen size	23 in. diagonal
Battery/line operated	12/14 v dc, or 230 v 50 Hz ac
Reliability	2000 hr MTBF
Minimum operational life	7 yr

Progress of Development Work

Keeping the stringent requirements of the community TV set, viz., rugged in operation, economical in fabrication and in low power consumption, a preliminary solid-state TV set has been developed. The set design was begun by choosing the best components and devices. As a second step, after successfully establishing the performance characteristic, device and component change is introduced to effect economy and still maintain the performance.

In order to improve the performance and to make the receiver more rugged, the following improvements are being tried out: 1) integrated circuitry to replace the sound and the signal handling portions of the TV receiver; 2) modular construction for simplifying maintenance; 3) a door locking system provided with a microswitch to automatically take care of the ON-OFF operations of the receiver; and 4) all the important controls at the rear with a locking arrangement to prevent handling by any one except the maintenance supervisor.

The front end converter, which is an important unit of the community set, is developed in two parts as an antenna mounted "head end" and a "tail end" attached to the receiver. However, for obtaining cost saving as well as minimizing the number of components, an integrated function direct receiver is being developed.

Power Sources

At present less than 20% of the villages in India are electrified and there are about 560,000 villages in the country. In order to provide television reception from a satellite in every village, one obviously has to think of alternate power sources to run the direct receivers. The problem of providing economical means of supplying power to the TV receiver is an important one. The possible sources of power which can be considered for this purpose are shown in Fig. 1.

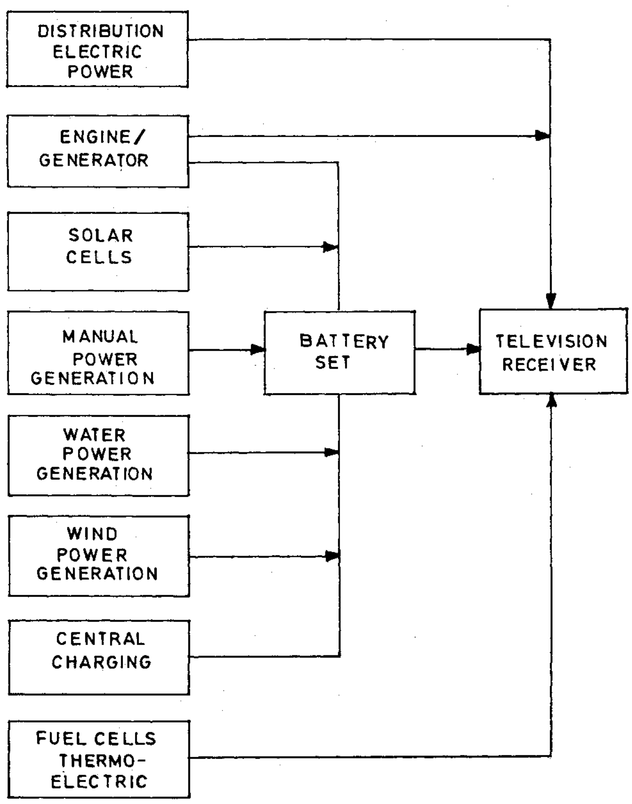

Fig. 1 Receiver power sources.

As is shown, three power sources are capable of supplying power directly to the receiver, whereas the remainder of the sources as well as the engine generator can be considered for charging the batteries used for the TV receiver.

Discussion

A detailed techno-economic study has been made taking into account the receiver requirements with the basic assumption that the community TV set is solid state in design and is battery operated. Considering the existing costs of power sources, the annual cost for different power requirements are presented in Figs. 2 and 3.

For this it may be seen that the most likely candidate for a receiver power source is an automative-type battery set which is periodically recharged by gasoline/kerosene or diesel engine generator unit. An important consideration, however, is the incremental cost of power. The cost of additional power from battery source is almost in direct proportion to the power required (i.e., 1200 w hours at a cost of $0.75 per charge). Whithin the range of capacity of the diesel engine generator unit, additional power is obtained primarily at the expense of additional fuel. For the distribution line the incremental cost is simply the cost of power consumed.

Cost of Power Sources

In order to get a comparative idea on the power sources an example pertaining to nation-wide coverage for India is presented below. The following assumptions are made for this example: a) television receivers will be deployed at an annual rate of approximately 90,000; b) of these one-third will be supplied to villages having electric power, one-third to villages having reasonable access to electric power for battery charging and the remaining one-third to villages to which power must be supplied; c) of the power sources, capital equipment only will be supplied, that is, direct costs of procurement of batteries and engines/generator units; d) the maintenance cost, fuel and battery charging is borne by the village.

Of the 550,000 villages in India, if it is assumed that by 1974 150,000 will have electric power, and this number will increase at the rate of 10,000 per year; villages having reasonable access to electric power for battery charging will be 250,000 with an annual increase of 10,000. Then, 150,000 villages will require power sources and this number will decrease at the rate of 20,000 per year. The situations described are illustrated in Figs. 4–6.

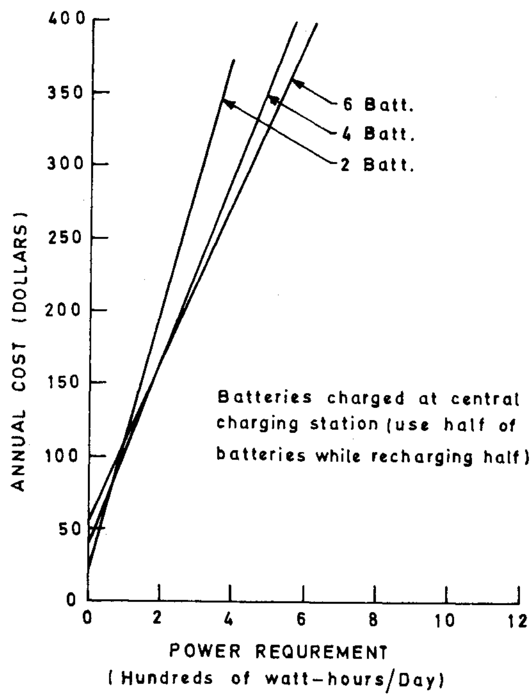

Fig. 2 Annual cost vs power requirement.

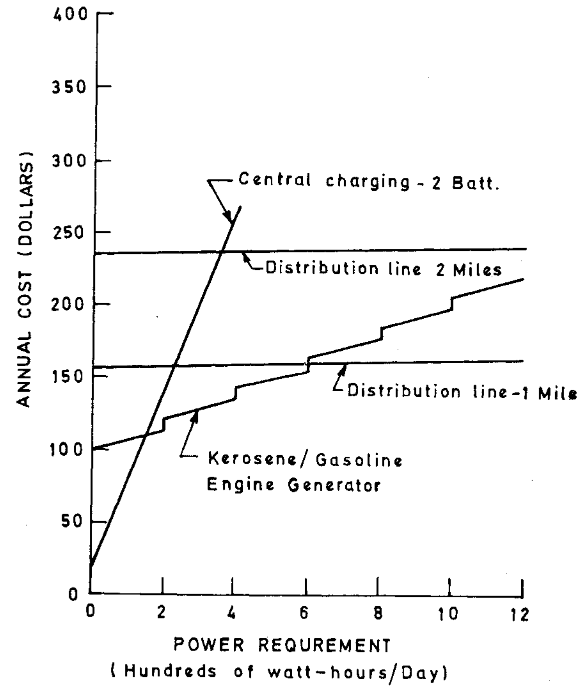

Fig. 3 Annual cost vs power requirement.

As shown in Figure 6 the receivers deployed to villages requiring power sources reach a peak in 1976 and then decline as the number of villages requiring a power source declines. The proportion of the receiver production which has been allotted to these villages is then allotted to those villages having access to power sources as illustrated in Fig. 5.

These studies conducted with respect to various aspects mentioned previously have resulted in three possible power sources for the community receivers. Further, it has been postulated that the power consumption of the TV set would be minimized and if this is agreed to then the following three possibilities exist as possible approaches. 1) Wherever possible, use should be made of existing power distribution lines, where a village is situated within 2 miles of existing lines, extensions to the villages should be made. 2) For distances greater than 2 miles from a power source, engine/generators should be used for central battery charging with capacity great enough to service villages within distances. 3) To service all villages with battery operated sets at distance greater than 5 miles, an engine/generator in each village would be economical.

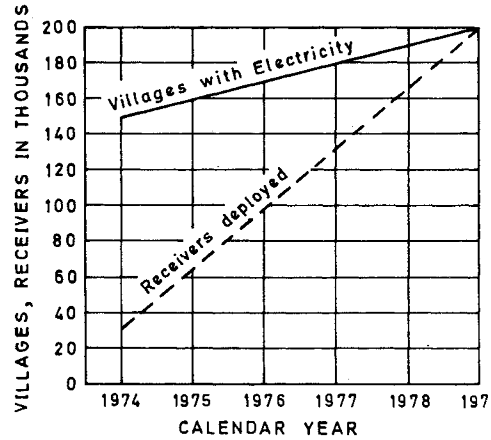

Fig. 4 Number of electrified villages and receivers alloted vs time.

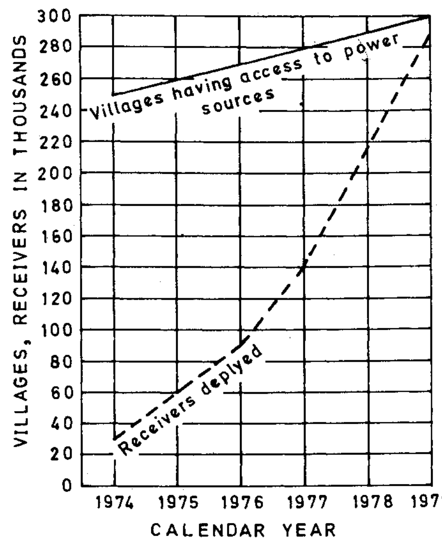

Fig. 5 Villages having access to electricty for battery charging and receivers deployed to these villages.

During Satellite Instructional Television Experiment, some of the TV sets will be located in unelectrified villages. These sets will be operated from various power sources so that the costs and problems of each can be evaluated in the actual field situation. These data will be of great use in the planning and setting up of a national system, which will cover also the vast number of unelectrified villages in the country.

Maintenance Assumptions

The maintenance analysis is based on the following assumptions: a) the TV set is a solid state one; b) the TV is made up of a number of modules that can be removed from the set for maintenance; c) a very large number of these sets will be operated on batteries in nonelectrified villages; d) the sets have been designed and ruggedized specially for use in villages and for transport over bad roads; e) the designed mean time before failure (MTBF) is over 2000 operating hours; f) the sets will be in operation for about 4–8 hr/day initially; g) the antenna requires practically no maintenance, though periodic re-adjustment may be necessary.

Organization for Maintenance

The maintenance organization can be composed either of a few very big centers covering large areas and handling a very large number of sets, or a large number of smaller centers. If the first alternative is used, which is highly centralized type of system, then two approaches are possible. 1) The faulty sets could be picked up from the villages by a jeep provided by the center and taken to the center for repairs. 2) the villages could be asked to bring the sets to the center. (The third possibility of sending a technician with the jeep is not considered as it is obviously less attractive as the technician will be spending half of his time in travel. However, the jeep driver could be trained to perform some initial level of maintenance).

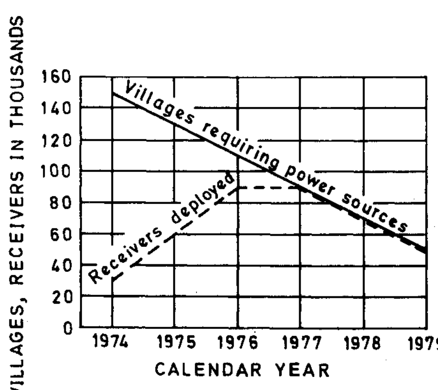

Fig. 6 Villages requiring power sources and receivers deployed to these villages.

The second alternative from all considerations, appears to be more practical and realistic. It could consist of a large number of small servicing centers backed up by a smaller number of medium sized centers. This is a three tier approach with two distinct levels of servicing. The lowest level (tier 1) would cover an area small enough to enable the villagers themselves to bring the sets to the center. A reasonable maximum distance was estimated to be about 20 miles sets from the villages could be brought by the villagers to this center by means of mechanized transport (buses) or bullock carts. Thus, each of these tier 1 ecnters can reasonably cover an area of about 1000 square miles. An area of this size would, on an average, have about 500 villages, i.e., 500 community sets and the center should be capable of servicing this number. The envisaged center would be manned by one technician who would have the equipment (1 VTVM, 1 Multimeter) and tools necessary to attend to simple defects. He will also have an inventory of modules and will use these to replace faulty modules which he cannot repair. His functions will be to diagnose the fault, replace the module (if required) or carry out the repairs necessary (if he can), and to repair whatever modules he can. The sets or modules which he cannot repair will be sent to the next level centers (tier 2). Thus, the technician will take care of all the normal faults that arise in a set, and it is estimated that he will take about 1 hr per set. He is therefore capable of handling about 2000 repairs per year. Using the assumptions in the preceding paragraphs (MTBF 2000 hr, daily usage about 6 hr), it is seen that each set will require repair only once a year. Thus, each technician can very easily handle an area of 1000 square miles, and there will be 1000 such centers covering the entire country. These centers can be located at the block offices or at other suitable locations.

The next level of centers have two sublevels. Tier 2 and 2A. As far as the actual maintenance work is concerned, both these are the same. They consist of five technicians supervised by one engineer. The functions of these tier 2 centers primarily is to repair modules and sets which cannot be repaired at tier 1 and to supervise the operations of the tier 1 centers. These two tiers will be nominally controlled at the highest level through the central office, which will perform a purley administrative (as opposed to actual maintenance) function. It will have a total of about 15 people working in it, of which about three should be engineers, who can handle inventory problems and help information flow to and from the lower levels and the factory.

Conclusion

The spread and efficient use of satellite television will primarily depend upon the direct receivers which can be used in villages and can operate on batteries. The factors to be kept in view with regard to these receivers are the cost, reliable operation, picture quality, etc. Since in most of the developing coutries, electric power is a problem (particularly in villages), efficient power sources have to be developed and that too at reasonable costs. Further the community set design should minimize the power consumption to the extent possible to ease the power supply problems.

In addition to introducing better designs and ensuring high reliability of operation, one has to carefully plan an efficient system of maintenance. This and this alone would contribute to reliable operation of the TV sets in villages. All these problems exist now and no definite solutions exist to date.

Since the Satellite Instructional Television Experiment will be performed during 1974–1975, one could expect to find answers for many of these problems. This is a vital step before launching any large-scale operations in the area of satellite broadcasting.