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ATS-1 in perspective

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Introduction

The expectation of a national communication satellite system by 1985 and the availability of NASA's ATS-1 satellite for prior experimentation have aroused a high degree of interest in the possible use of satellite communication for educational, community development, and other public-welfare applications in Australia. Potential users in these areas are often referred to as "small users" due to their small scale of operation and low volume of traffic demand.

Several small user groups have already acquired low cost earth stations and are carrying out experimentation using the two-way voice bandwidth facility on the ATS-1 satellite for point-to-point, broadcasting and teleconferencing applications. These groups are coordinated within the PEACESAT Australia project. All the earth stations are connected together into a network called the Kangaroo network. They also have access to several Pacific wide networks which are serviced by the same satellite. ATS-1 has been used successfully for voice, facsimile, teletype, slow-scan television and computer communication.

The main objective of the PEACESAT Australia project is to give small users an opportunity for experimentation to discover their specific areas of application which would be best served by satellites. The next step would be an investigation of costs and benefits as well as ways and means of accessing an operational satellite system which would satisfy the proven need on a permanent basis. The most obvious option to be investigated in Australia is the use of the AUSSAT system expected in 1985.

The low user cost, ease of access and ease of utilisation of ATS-1 may give experimenters a false sense of the economics of satellite communication and thus an unrealistic expectation of the capabilities of current technology. This paper discusses the current usage of ATS-1, the advantages and limitations of this particular satellite, and future possibilities as far as Australia is concerned. AUSSAT features prominently as one of those possibilities. It is hoped that the paper will be of particular help to those people who are using the ATS-1 during the experimental phase and are now in a position to plan and make decisions regarding the use of AUSSAT first and second generation satellites.

The ATS-1 Satellite

ATS-1 (Application Technology Satellite) was launched by NASA on December 7, 1966 (1). It was a pioneer in geo-stationary satellite communication technology and was designed to carry out experiments to pave the way for operational systems. Among many other facilities the satellite carries a VHF (Very High Frequency) transponder which has enough bandwidth for 5 voice bandwidth channels. At the beginning of its life it produced a maximum of 40 watts of RF (Radio Frequency) power. The antennas were of very simple whip-array construction, giving a global beam covering 40% of the surface of the earth. It was positioned at 149 degrees West longitude, giving a footprint coverage between points as far West as Lae in Papua New Guinea and Washington DC in the USA.

The satellite was designed to carry out NASA's own experiments for a period of 3 years. At the end of this period NASA invited proposals for the use of the satellite by small user groups in the Pacific and on the American continent. Several projects were initiated (2), including PEACESAT (Pacific Educational And Communication Experiment by Satellite), USP (University of South Pacific), ALASKA (Medical network) and DISP (Department of Interior Satellite Project). These projects were permitted to use the satellite as long as the station keeping and electronic systems remained operational.

Technical problems developed with the station keeping systems in April 1979, foreshadowing the reduction of usefulness to only 3 more years. A decision was made to move ATS-1 Westward in January 1982 to 164 degrees East Longitude in order to conserve fuel. At this new location it is estimated that the satellite can be maintained in position until at least 1993. However, any failure in the electronic system would terminate the usefulness of the satellite before then. At this position, all parts of Australia can access the satellite. The new position corresponds closely to one of the planned positions of AUSSAT.

Current usage of ATS-1 in Australia

During September 1983 there was a total of 23 ground stations operational in Australia within the Kangaroo network with 3 more already licensed. It is expected that at least 15 more stations will be fully operational by 1984. These stations belong to various small user groups such as the University of Sydney, La Trobe University, SA Educational Technology Centre, the University of Western Australia, Darling Downs Institute of Advanced Education Victoria Police, WA Police, NSW Police, NT Police, SA College of Advanced Education, Footscray Institute of Technology, Darwin Community College, Canberra College of Advanced Education, Queensland Police, WA Institute of Technology, Australian National University, Australian Federal Police, Deakin University and WA Education Department.

The use of ATS-1 in Australia is coordinated from La Trobe University. Voice and computer teleconferencing are conducted regularly within 10 sub-networks which include regular and occasional stations, Packet Switching, Primary/Secondary Education, Police, Tertiary Distance Education, NT School of the Air, Batchelor College, WAIT, Public Broadcasting and Queensland State sub-nets (3). These sub-nets are convened according to a predetermined schedule.

The advantages of ATS-1

There are many distinct advantages of ATS-1 for two-way voice bandwidth teleconferencing and classroom applications. As with most communication satellites, FM (Frequency Modulation) is used. Hence static interference is reduced when compared to the terrestrial SSB (Single Sideband Modulation) high frequency (HF) system commonly used in distance education in Australia.

Because of the use of VHF, very high power can be produced at the satellite using well developed technology. With very simple on board antennas, sufficient power reaches the earth to enable reception by very small and inexpensive ground receivers when the full power of the satellite is utilised to provide a single voice bandwidth transmission.

Two-way communication to and from the satellite is possible at very low cost on the ground because at VHF frequencies the transmitting and receiving equipment are readily available off the shelf. This equipment has been used for more than 3 decades in terrestrial applications such as two-way mobile and amateur radio services. Typical cost is $2,000 for a complete station using commercially available equipment. Some stations are constructed locally for lesser cost.

The global coverage of ATS-1 is a desirable feature for international and regional networking. At its present position ATS-1 can be accessed from South-East Asia, Japan, Australia and the whole Pacific region.

ATS-1 is directly accessible from ground equipment at the individual user's premises. No complex switching or DAMA (Demand Assigned Multiple Access) facility is needed.

The two-way access operates in the half-duplex mode. This means that only one station may transmit to the satellite at any one time, but this transmission is received by all stations in the network simultaneously. Operationally the transmission is initiated by a press- to-talk button or switch. Network operation and discipline are similar to those used in HF networks such as the School of the Air. Although this mode of operation is not suitable for telephony-type private-line full-duplex applications, it is simple and cheap to implement. It has the advantage that only one talker is permitted at a time, thus promoting a very desirable network discipline on the users.

Another great advantage of the half-duplex mode of access is the inbuilt ease for teleconferencing and classroom applications. Only one single voice channel is needed by the network as a whole, independent of the number of stations in the network. In contrast, a similar teleconferencing arrangement using terrestrial and some satellite telephony configurations would engage twice as many voice channels as there are users in the network. In addition, the latter facility involves extra expenses and the inconvenience of having to arrange the teleconferencing interconnection through at least one telephone exchange. In the case of telephony type conference by satellite such complex switching arrangements would normally be accompanied by "double- hop" transmission delays, whereas only a single-path delay is involved in the ATS-1 system. It is noted however, that a similar single voice- channel party-line arrangement to provide for unique educational requirements could be set up using a transponder on a domestic satellite.

The disadvantages of ATS-1

Although providing reasonable service at the present, the 17- year old equipment on board the satellite could malfunction at any time. Signal quality is not constant, being affected by polarisation changes, orientation of the satellite, state of the batteries and the age of the solar cells.

The biggest disadvantage of ATS-1 is the limitation of bandwidth. Although the bandwidth is wide enough for 5 voice bandwidth channels, it is only practical for 1 channel to be used at any one time because of the power limitation of the satellite. When more than one channel are used simultaneously, the limited power is shared among the users. Each user has a reduced power allocation with corresponding heavy reduction in signal quality. The user who transmits the most powerful signal to the satellite will over-ride all other users due to the FM capture effect. Another disadvantage is the presence of intermodulation distortion when more than one channel is used because of the non-linearities in the transponder.

To provide the single channel capability a total of 40 watts of RF power is needed. This power level is easier to produce at VHF compared to microwaves. However, the same amount of power at microwave frequencies, where much greater bandwidths are available, could support up to 1000 voice bandwidth channels. To reduce the power per channel required by the VHF satellite would require very large VHF antennas. A satellite with large deployable antennas is extremely expensive to launch into space.

There are no commercial satellites available for VHF at the present although there are plans for an experimental UHF (Ultra High Frequency) system. The equipment being used for ATS-1 now will not be directly applicable to commercial satellites as a complete replacement of the RF equipment and antenna system will be required.

Because of the very heavy use of VHF frequencies for terrestrial services, there is no provision in the international table of frequency allocation for VHF satellites except for amateur services. Even then the allowable bandwidth is very limited and could support only a very small number of voice bandwidth services.

VHF permits the use of very inexpensive antenna systems on the ground. A very simple structure provides a large capture area for receiving radio signals, and pointing is not critical. This low directivity does have its disadvantages however, because it does not provide good discrimination against signals from closely spaced adjacent satellites. VHF satellites would therefore have to be widely spaced in the geostationary orbital arc, and the total capacity for telephone communications would be quite limited.

Use of the ATS-1 is now free but realistically, in advocating the provision of a single VHF telephone channel for use over the Pacific, the potential cost of the channel has to be considered. One method of assessing the possible cost is on the basis of the RF power Forty watts of RF power on ATS-1 is equivalent to one sixth of the total RF power of an AUSSAT satellite. A direct extrapolation from the projected charges for the total RF power of the AUSSAT transponders on one satellite would imply that one VHF telephone channel would cost about $5m per year. a high cost for this voice service which would have to be borne by the users of the single channel. (The actual costing should take into account the fact that a single channel VHF transponder is less expensive than a multi-channel Ku-band transponder to manufacture).

Possibilities after ATS-1

For Australia, the most obvious outcome of ATS-1 experimentation for small user groups is an appropriate use of AUSSAT facilities. This possibility is discussed further in the next section.

There may be economic and other reasons why the small users in Australia will not be able to utilise the first generation AUSSAT system. For example the volume of traffic may not justify the charges for satellite transponders or the cost of ground equipment. In these cases it may be economically attractive to examine other regional and international systems which can provide a very large coverage area. The aggregation of small users over the Pacific and Asian regions may make the use of satellite facilities cheaper than the aggregation over Australia only. In addition, a wider footprint covering such a large area would require much simpler antennas on a satellite and make practical the use of frequencies such as UHF to support cheaper ground stations (4). Some possibilities are listed below.

INTELSAT is considering special reduced rates for small users in the Pacific region (5). Australia already has some experience in the use of INTELSAT facilities for remote areas. The technology for 6/4 GHz frequencies used on INTELSAT is well established.

There is likely to be some spare capacity on board NASA's TDRS (Tracking and Data Relay Satellite) system for use in the Pacific region. NASA is investigating the use of simple ground stations for this purpose. Such ground stations are also useable for the INTELSAT system.

At the Pacific Telecommunications Conference (PTC-83) there was extensive discussion on the possibility of a regional satellite system to serve those areas currently within the ATS-1 footprint (6).

Another possibility is the GLODOM (Global-Domestic Satellite System) concept proposed at ITU (International Telecommunication Union) for the sharing of satellite facilities by developed countries with the developing nations.

On the UHF range of frequencies there are several possibilities, for example, the INMARSAT and the AMATEUR satellite systems. The development of MSAT (UHF Mobile Satellite) by NASA and the Canadian Department of Communications also merits a close study.

It is possible that the second generation AUSSAT will also include some provision for access by Western Pacific countries.

Prospects for use of AUSSAT

The first two AUSSAT satellites are scheduled for launch in July and October 1985. They will each have eleven low power (12 watt) and four high power (30 watt) transponders and will operate in the internationally designated Ku satellite communications band of 12.25 to 12.75 GHz (500 MHz wide). Each transponder will have a bandwidth of 45 MHz which is sufficient to accommodate a maximum of 1,000 voice bandwidth channels, an equivalent number of data channels or a television signal. The transmitted power of each transponder will be concentrated into a beam which covers either all of Australia or one of four contiguous regions or zones in Australia or all Papua New Guinea, depending upon the individual transponder and the option selected for beam switching (7, 8).

There will not be the capability on the first generation Australian domestic satellites to cover south Pacific Islands or the full hemisphere potentially visible from the satellite. The capability of these satellites is concentrated over Australia and optionally on Papua New Guinea. Because the satellites operate at microwave frequencies, it has been possible to obtain the concentration using antennas on the satellite which are approximately 1 m in diameter, a size that can be accommodated very easily. To obtain the same concentration of power at VHF would have required an antenna of almost 90m in diameter, a size which would challenge the capability of the present satellite technology. (These factors, together with the wider bandwidths available at the higher frequencies, determined that the first domestic satellite system would have to operate at microwave frequencies).

Given the uncertain life of ATS-1, it is important for the users of ATS-1 to assess the capability of AUSSAT to meet their needs. As discussed previously, AUSSAT will provide communications only over Australia. This will preclude exchanges with the Pacific Islands via this satellite. Within Australia, however, it would be technically feasible to design a single voice bandwidth channel using a small part of one transponder in a national beam. Within Australia, this channel could be used in exactly the same manner as the transponder on ATS-1. Participants would need to observe the same scheduling and network discipline as invoked for ATS-1. This single channel could be accommodated within a 12 watt transponder that was also allocated for other single channel per carrier communications purposes.

A typical earth station to use this shared voice bandwidth channel would have an antenna diameter of 2.5 m, a transmit power level of about 1 watt, and a receiver noise figure of about 2.5 dB specifications which are similar to those prepared by AUSSAT for minor earth stations. Present indications are that such earth stations would cost about $25,000 and there is some potential for cost savings if an earth station was assembled from subsystems It is possible that towards the end of the 1980s a transmit/receiver earth station could cost about $10,000.

With earth stations of this type, it has been estimated that approximately 200 voice bandwidth channels could be accommodated within one 12 watt transponder. On the basis of notional charges for transponder lease, it could be estimated, on a pro rata basis with some allowance for partial use charges, that lease charges for a voice bandwidth channel would be somewhat below $20,000 per year (9).

The capital cost of earth stations and the notional lease charges establish the scale of expenditure that would be needed for use of the voice bandwidth channel.

Policies regarding the potential for lease of partial transponder capacity from AUSSAT and the ownership of transmitting earth stations are still being determined. The constraints that might be imposed upon a common interest group joining together to share a voice bandwidth channel are therefore still to be defined. If such use is provided for, it would be necessary for such users to cooperate closely with AUSSAT to aid AUSSAT's development of a workable administrative and technical arrangement for sharing the use of a single transponder.

Sharing of a transponder for a number of independent services is already being considered by some agencies. Among these are the Departments of Education who, in co-operation with the Department of Communications, are developing concepts for the use of the satellite by the schools of the Air, in the different states (10).

One concept involves each school of the Air class using two voice bandwidth channels, one for the teacher and one time-shared for students' responses. All of the present 18-20 simultaneous classes of the Schools of the Air could share a single transponder. Consideration is being given to use of voice/receive only and transmit/receive earth stations somewhat smaller than 2.5m in diameter to reduce logistics problems but recognising that use of smaller earth stations would decrease the total number of voice bandwidth channels that can be provided through one shared transponder.

Conclusions

The ATS-1 satellite has proved to be a boon for Australian small users to obtain first hand experience in satellite communication and to explore the areas of application best suited to this technology. Many small user groups are taking advantage of this opportunity.

Although the access and utilisation of ATS-1 is very convenient and involves very little cost, the carrying over of the experience to a more permanent set-up requires much thought and planning. The ATS-1 technology has severe limitations. This technology is not available on existing or future commercial systems.

AUSSAT offers facilities which could be useful to Australian small users. Current studies by AUSSAT and the Department of Communication have paved the way toward the exploitation of these facilities. For reasons of volume of traffic and areas of coverage, some needs which have been revealed by the ATS-1 experience may be met more economically by different systems on a shared basis with other regional and international small users.

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