Satellite communications, Project UNIVERSE and local area networks

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Summary The article discusses a high-speed digital communication system in which a satellite is used to interlink a number of local area networks comprising a variety of computer facilities. The advantages of satellite communications against terrestrial links are detailed, together with a historical survey of the use of OTS for data experiments and the involvement of Marconi Communication Systems in those experiments.

A description of Project UNIVERSE, which is the latest use of OTS, is given and the purpose of the project is described along with a more detailed description of the elements that make up the network, such as satellite earth terminals, communication rings and terrestrial links.

In addition to the description of the Project UNIVERSE programme and its purpose and function, the article considers future developments of such systems and their use as a means of business communication. In particular, the factors affecting their growth are considered, emphasis being placed on the specification and cost of terminal equipment.

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Introduction

The existing terrestrial communication networks in developed countries have until recent times relied upon frequency division multiplex (f.d.m) trunk systems to fulfil their main communication needs. Since the late 1960s administrations have been considering the use of digital transmission in their networks, using time division multiplex (t.d.m) techniques. British Telecom (BT) made a policy decision in 1972 to use digital transmission in the network and, since that time, there has been a steady growth of digital equipment starting with the use of 24-channel pulse code modulation (p.c.m) and now extending into the local area networks with such equipment as KiloStream and MegaStream[1].

The transmission of data within the public network is at present restricted to 48kbit/s services using leased lines. This facility, although adequate for certain services, is already insufficient for the transmission of bulk data between business centres, be they banks, industrial concerns or research establishments. It will be some time before these services are available using terrestrial networks. The alternative to a terrestrial system is, of course, a satellite-based data system using small data terminals situated directly on customer premises, which has several unique advantages over a terrestrial system. These are:

a) the system is not distance dependent;
b) point-to-multi-point communication is possible;
c) the network can be expanded easily or be re-configured;
d) the quality of the link is often better than the terrestrial system, though the propagation delay can be a problem;
e) a high-speed link can be available, depending purely upon the satellite design;
f) the service can be secure and independent of the common-carrier network if encrypted.

The practical realization of such a satellite system is currently to be seen in the United States and will eventually be seen in Europe when the European Communication Satellite System (ECS) and Telcom 1 systems become fully operational.[2] These systems are seen as being able to provide new services additional to those available from terrestrial networks and great emphasis is being placed on the role satellite communications can play in the office of the future, with facilities for electronic mail, high-speed facsimile, video teleconferencing, etc.

The wide range of possible applications for the system have not yet been explored fully and it is as a part of that exploration that Project UNIVERSE has been set up, using the Orbital Test Satellite (OTS) as part of the distribution system. UNIVERSE is an experimental system using OTS, the forerunner of ECS.

Project UNIVERSE

The UNIVersities Extended Ring and Satellite Experiment (UNIVERSE) is a project designed to investigate the facilities and protocols which will need to be developed to provide digital business communications by linking together terrestrial and satellite networks, with particular emphasis on the use of communication rings for distribution within local area networks.

The project has participants from Rutherford and Appleton Laboratories, Cambridge, Loughborough and London Universities, GEC Marconi Research, Logica Ltd. and British Telecom. It is funded by the Department of Industry, the Science and Engineering Research Council, BT, GEC Marconi and Logica and is scheduled to last a period of three years.

The OTS System

Project UNIVERSE will use the OTS satellite which, although now almost beyond its design life, is being used for a number of experiments. The project can be seen as an extension of the OTS Project which was initiated by the European Space Agency and was designed to evaluate satellite communication performance in the 11/14GHz band as a forerunner of a European Communication System now being implemented in Europe.

Satellite business system experiments using OTS were carried out between 1979 and 1981, involving two separate networks. The first experiment, called STELLA, linked Rutherford Laboratory (near Oxford), CERN (Geneva), DESY (Hamburg) and CNVCE (near Paris). The second experiment linked computers in European Space Agency (ESA) establishments in Italy, Germany, Holland and the Royal Aircraft Establishment (RAE) in UK and was called SPINE.[3]

The experiments were carried out to evaluate link performance at 512kbit/s and 1024kbit/s data rates. These bit rates were most suitable for transferring data between remote computers having large storage capacity – greater than 300Mbyte. Each computing centre shared the same satellite channel, using a time division multiple access (t.d.m.a) system, with a master station providing a timing reference for a data burst from each working station.

Marconi Communication Systems (MCS) was involved in both experiments, providing small data terminals at CERN, Rutherford Laboratory, RAE Farnborough and Darmstadt. In addition, MCS designed and built one of the main 19m control stations at Goonhilly Downs, Cornwall.[4]

Communication system

The system is made up of the following components:

a) the satellite links (described later in this section);

b) the local distribution network at earth station sites in the form of digital communication rings;

c) terrestrial links between University College, London, (UCL) and Logica capable of operating at Mbit/s data rates;

d) X25 Nets, using the BT public network Packet-Switched Service (PSS) and SERCNET, which is the network operated by the Science and Engineering Research Council.

Project UNIVERSE data terminals

The data terminals for the Project UNIVERSE experiment use MCS design with MCS providing all of the terminals apart from the facility at Martlesham.

The data terminal, the block diagram of which is shown in figure 1, provides the means of transmission to, and reception from, the OTS satellite. The terminal itself can conventionally be divided into two parts – the antenna and the equipment cabinet.

Antenna

The 3m diameter antenna is made up of three parts, parabolic reflector, feed and sub-dish. The parabolic reflector is of moulded glass fibre, the moulding process being of high precision in order to obtain the required surface contour accuracy. The reflecting surface is sprayed with a layer of aluminium. The feed system is a conical corrugated horn followed by a polarizer and orthogonal mode transducer. The polarizer characteristics can be varied to produce orthogonal linear or orthogonal circularly-polarized signals. The sub-dish, illuminated by the feed, forms a single unit with the feed assembly.

The main dish is provided with a rigid support and can withstand wind speeds of up to 200km/h, though to achieve this, should the antenna be roof-mounted, it is likely that the roof will require reinforcement. The installation at Marconi Research Laboratory is shown in figure 2.

The antenna is designed to work over the 11·45–11·8GHz receive band and the 14·0–14·5GHz transmit bands. The antenna receive gain is 49·2dB and transmit gain is 50·8dB. The figure of merit, (G/T), at 30° elevation is 22·5dB/k with the low-noise amplifier being mounted directly on the back of the dish. The transmitted

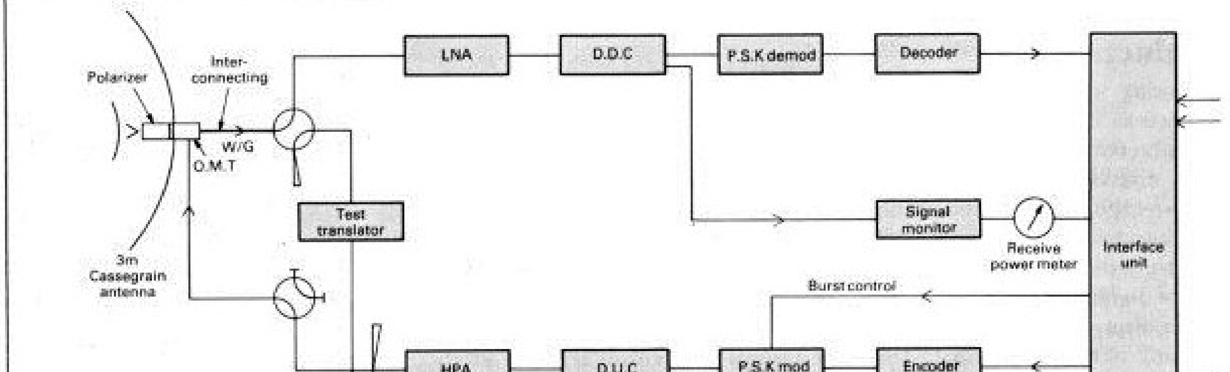

Fig. 1. Block schematic of a data terminal for Project UNIVERSE

equivalent isotropic radiated power (e.i.r.p) is 71dBW maximum.

With such a size of antenna the main beam diameter is wide enough to obviate the need for an automatic tracking system. However, the antenna position can be varied in both azimuth and elevation and the user has the option of a manual screw arrangement or the possibility of remote control by use of motorized jack screws. The antenna movement is limited to ±25° azimuth and between 0 and 57° elevation, which should be quite sufficient provided that the basic antenna site is in a south-facing position.

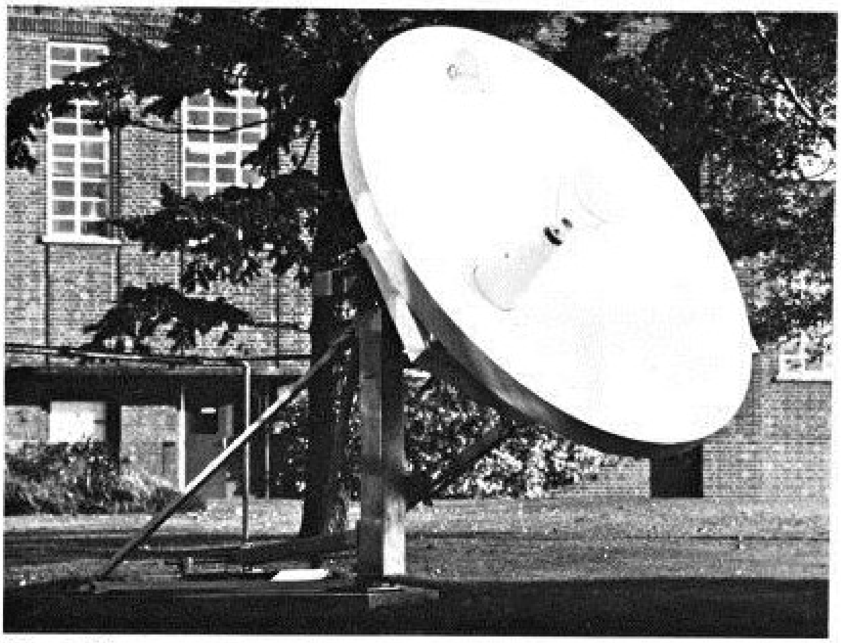

Fig. 2. The antenna installation for Project UNIVERSE at the Marconi Research Laboratories, near Chelmsford, Essex

Equipment cabinet

The internal equipment is mounted in a free-standing cabinet which can be situated remote from the computer facility. The overall equipment provides both upconverter and downconverter chains.

Transmit path

The signals between the data terminal and the computer facility are processed in an interface unit which converts TTL data signals into balanced differential signals for transmission to the computer and takes the balanced differential signals from the computer and converts these to TTL levels. This means that interconnection can be made to the computer at distances up to 100m using twisted-pair cables. In addition, d.c status signals are converted to TTL and thence to a balanced differential form, also power level indication is processed for remote indication.

The processed signals to be transmitted at 1Mbit/s are applied to a convolutional encoder, though the system allows direct application to the 2-phase modulator, if required, by operation of a front-panel switch. In order to eliminate phase ambiguities, differential coding is used. The encoded signal spectrum is shaped by a channel filter before being linearly modulated directly on to the i.f carrier at 70MHz. The system can operate either in continuous or burst-mode operation. In burst-mode operation the burst control signal switches the carrier on and off. During off periods the output level control is disabled and a track-and-hold facility prevents the output stage gain from going to maximum and thus prevents high noise output during off periods.

The modulated carrier is applied to a double upconverter unit where it is converted to the 14GHz band with a first i.f of 770MHz and local oscillator at 700MHz. The second local oscillator can be switched between two frequencies by switching reference oscillators. The unit provides an indication of lock status for the local phase-locked oscillator (p.l.o).

The double upconverter (d.u.c) output passes via a filter/circulator to an intermediate travelling-wave tube (t.w.t) amplifier which raises the transmit level to 10W. This output is then applied to a second t.w.t amplifier which raises the transmit level to 140W. The power output can be controlled both at cabinet level and from a remote position, as can the monitoring of output power levels. The transmit signal is applied to the antenna feed via a circulator and waveguide switch to allow disconnection from the feed when required.

Receive path

The signal from the satellite is fed directly to a f.e.t amplifier having a bandwidth of 350MHz, a gain of 25dB and a noise figure of 2·5dB. The amplifier output is fed via a waveguide switch which allows the received signal to be filtered and connected to the receive downconverter, or allows the test translator output to be used for checking the receive system without accessing the satellite. The 11GHz signal is applied to a double downconverter module which processes the signal to produce a 70MHz i.f output at a level of −25dBm. The p.l.o status can be seen on the front panel.

The downconverter output is fed to an interface module and to a directional coupler where the signal is split into two paths. One path feeds a signal monitor module which processes the signal before applying it to a receive power monitor. The filter in the signal monitor module is specially calibrated for noise bandwidth and also for carrier power loss when the carrier is modulated with a pseudo-random sequence. Thus the link performance can be checked and the unit can be used for C/N measurements. The other path is to the demodulator module to recover the data and clock information from the received signal. In burst-mode operation this has to be accomplished within a specific number of bits from the start of the burst. The design of the demodulator is therefore a compromise between rapid acquisition and loop bandwidth. The input amplifier provides not only signal amplification but also automatic gain control which gives a constant amplitude signal to the frequency lock loop used to remove frequency errors from the incoming signal bursts. The signal is demodulated to baseband, filtered and then upconverted for carrier recovery and coherent demodulation. The demodulated signal has then to be regenerated and decoded. The demodulated baseband signal is

Fig. 3. Data terminal at the Rutherford Laboratories, Oxford.

applied to a 3-bit analogue-to-digital converter which produces a soft decision signal suitable for application to the codec unit.

Network interconnection

One of the purposes of Project UNIVERSE is to look into the most effective means of connecting the various networks. Four types of gateway or bridge will be required.

a) a bridge between the satellite earth terminal and the communication ring;
b) a bridge between the site rings;
c) a bridge connecting the X25 network with the communication ring;
d) a bridge between the University College ring and the high-speed terrestrial link to Logica. This, in fact, is known as a terrestrial half-bridge.

The required bridges are either under development or in current use in local area communication networks.

Network configurations

Satellite

This network can be seen as that part of the system which interconnects the various communications rings at separate locations. The network obviously requires a satellite, in this case the OTS satellite, a ground station to receive and transmit the data and an interface between ground station and communication ring.

The ground station is similar to that used in previous OTS experiments and has already been described in detail. The interface comprises two parts. First, a satellite interface module using a Motorola 6800 processor which processes the data stream to and from the ground station, performing the multiplex/demultiplex function, synchronization, timing and framing. The second part is a link-driving computer which performs the packeting function. The computer, a GEC 4065 with 512kbyte of buffer store and two 4·8Mbyte discs, interfaces directly with the communication ring. One of the purposes of the UNIVERSE experiment is to gather information on the data rates that can be achieved through the link-driving computer.

The space segment data packets have a frame size of 125ms with the frame containing slots for the use of each transmitting earth station. The allocation of a data slot, in each frame, is made by the master ground station.

Communication ring

The need for interconnection of computers located close to one another has resulted in a considerable amount of work being carried out to find the most efficient means of communication between the various computers at each locality. There has been a variety of systems, such as Ethernet and the Cambridge Ring, and for Project UNIVERSE the Cambridge Ring system has been adopted, although at least one alternative system is also being used to maintain the generality of interconnection protocols. A typical system is shown in figure 4.

The Cambridge Ring, as its name implies, was developed at Cambridge University from 1974 onwards as a communication system in the form of a ring running round a number of buildings to connect, in a general way, a number of computer facilities.

The basic rate of the data is 10Mbit/s. At each facility is a station which is connected to the ring via an access box or repeater. Messages are passed from source to destination in the form of a number of discrete mini-packets. Mini-packets of 38 or 40 bits circulate endlessly around the ring and when a station has a message to transmit it seizes free mini-packets by flagging them as full, loads the next part of

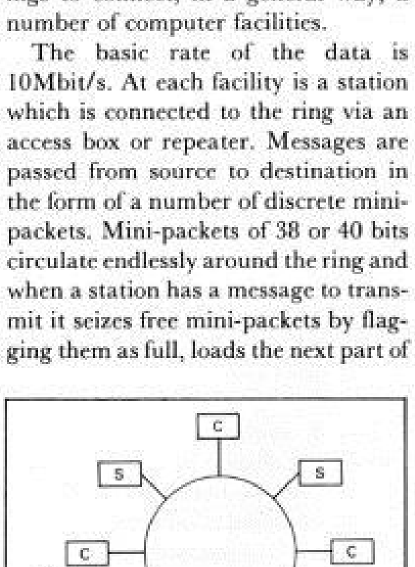

Fig. 4. Layout of a typical Cambridge Ring system

the message string and adds the source and destination addresses. All stations monitor the destination address block and, if there is a match, the data is removed and receipt acknowledged. The mini-packet circulates back to the source, which checks various 'housekeeping' bits, and releases the mini-packets. Control bits indicate the behaviour of the recipient, (e.g, 'data received OK', 'busy', 'off-line') and, depending on the messages, the source continues to seize mini-packets as available until the whole message is delivered.

The ring can be seen to have not only computers connected to it but also a variety of servers. Terminal servers use Z80A or 8080 microprocessors for concentration which allow a number of v.d.us to be connected to one station. The ring is managed by another server called the Resource Manager which allocates a computer, or computers, to the user and routes the user to other server functions such as file access, printing facilities, time signals, etc.

Project UNIVERSE will define protocols for the system with a view to achieving common protocols throughout the network. This standardization is necessary to prevent incompatibility between systems and, hopefully, will lead to international agreement on interfaces and protocols. The importance of this cannot be stressed too much if the growth of world-wide data communications by satellite is to take place in a trouble-free manner.

Terrestrial links

One of the areas of great interest for future high-speed data business systems is that of the characteristics of high-speed terrestrial links as tails from a satellite-communication facility over short distances. Although the use of satellite communication removes the need for long-distance terrestrial links it is still necessary to connect data on each communication ring. It is therefore part of the UNIVERSE experiment to look not only at new methods of interconnection, such as optical fibre, but also at existing methods utilizing cable and available modems. Loughborough University is to investigate the characteristics of a communication ring when wired with optical fibre, with paths up to 1km in length. This will involve some development work for the multiplexing and demultiplexing of signals on to the fibre.

In London, UCL and Logica are co-operating to make Logica part of the UCL ring and for this they are investigating the use of transverse screened cables over several hundred metres. The helical form of screen may provide better noise immunity and improved screening capability for twisted pair cables at lower cost and weight. In addition, this form of cable will be used for connection of ring bridges and also for transmission of standard p.c.m as used in the BT network.

The UNIVERSE programme

There have been several experiments relating to satellite business systems, mainly concerned with the mechanics of communication and the feasibility of the space and ground segment equipments. With the imminent implementation of the ECS system, and the availability of the satellite multi-services transponder, it is necessary to look at the system implementation as a whole. This is the main aim of Project UNIVERSE.

The business communication system includes satellite link, local network systems and wide area networking. The questions to be asked and equipment looked at will be:

a) the internal functions, their operation under different information loads and how easy it is to use the system;
b) equipment design for network interconnection, multiplexers/demultiplexers on optical fibre links, high-speed modems and computer interface systems;
c) data bearer systems;
d) system design requirements to accommodate the effect of the large delay on the satellite link;
e) more efficient satellite t.d.m.a systems;
f) Cambridge Model Distributed System design with regard to coding, packet size error, correction, security procedures etc.;
g) types of service that can be handled – voice, data transmission, teleconferencing.

In addition to the above, the project will try to identify the forward development requirements of a business communication system. It is obviously necessary to use, wherever possible, current equipment which is well proven and requires no extra capital spend to make it fit the system. However, new systems will undoubtedly require the development of new equipment to cater for the problems found under operational conditions. Project UNIVERSE will also address these problems. In particular it will review:

a) satellite earth station (s.e.s) terminal equipment;
b) s.e.s control and monitoring;
c) terminal equipment for the communication rings.

Future developments

Project UNIVERSE will provide a considerable amount of information on the operation, monitoring and equipment requirements of a high-speed data network. Through work carried out over a two to three-year span there will be many pointers towards future requirements, both in terms of equipment and network procedures. The project will be invaluable in that it is orientated towards a practical realization of a communication system which will be required in the near future. From the point of view of the equipment manufacturer, identification of future needs is most important because of the time lag involved in development of equipment through to full production.

Current experience shows that a network cannot achieve financial viability purely on the dissemination of high-speed data. It must also be able to provide a wide variety of services to any prospective customer. It is essential that any system should appeal to as wide a variety of potential users as possible. To this end it should provide voice as well as all the possibilities associated with data transmission, such as bulk data transfer, video transmission, teleconferencing, teletext, image transfer etc.

The need for maximum system utilization to obtain financial viability brings with it a dilemma. Greater diversity implies more complex terminal equipment, which implies higher costs leading to higher customer resistance to the use of satellite earth terminals and it could, therefore, end in lower system utilization.

To ensure maximum take-up of the facility, a number of factors should be taken into account:

a) the system should not be over-specified. Authorities involved in controlling and specifying terminal

equipment must recognize that to over-specify will simply increase costs and may well reduce demand;
b) the terminal user will not be interested in how far the equipment has gone in using state-of-the-art components. He is interested in equipment that will fulfil the basic system parameters;
c) the terminal should consist of a basic equipment providing the necessary functions but capable of expansion by means of plug-in modules to add extra facilities as required;
d) supervisory and monitoring functions should be simple, though it will probably be necessary to provide remote supervision facilities, either at a computer facility or within an apartment or office block depending upon the user's premises;
e) maintenance must be simple;
f) initial terminal costs must be low;
g) regulatory controls on terminal use must be kept to a minimum. The user must feel that he can easily change his terminal function without having to become involved in complicated bureaucratic procedures.

The possibilities inherent in the type of system being investigated in Project UNIVERSE are tremendous. Experience in the USA has shown that benefits to companies having a number of establishments remote from one another can be enormous in terms of lower cost and improved facilities. It has also shown that for those benefits to be realized, and for networks to grow, two main factors are necessary. Firstly, the system must provide the widest range of facilities. It must not concentrate purely on high-speed data services. Secondly, the market place should not be restricted by external authority. Any external controls should be concerned mainly with technical performance and not be involved in dissemination of network equipment.

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RÉSUMÉ

L'article décrit en détail un système de communications numérique de grande rapidité, dans lequel un satellite est utilisé pour établir l'interliaison d'un certain nombre de réseaux locaux, dans lesquels sont intégrées diverses installations d'ordinateur. Les avantages de communications satellites, par rapport aux communications terrestres, sont exposés dans les détails, ainsi qu'une étude de l'historique des expérience qui ont été faites dans l'emploi d'OTS pour transmission de données avec description de la participation de Marconi Communication Systems à ces expériences.

Une description est donnée du projet UNIVERSE, qui est l'application la plus récente d'OTS, et le but du projet est décrit, ainsi que, et d'une façon particulièrement détaillée, les éléments constituant le résau tels que les stations terrestres de communications satellites, les circuits de communications et les liaisons terrestres.

Outre la description du programme de projet UNIVERSE, de son but et ses fonctions, l'article examine les développements dans l'avenir de systèmes de ce type et les applications qui peuvent en être faites pour les communications affaires. Les facteurs dont dépend l'extension du projet sont étudiés, en apportant une attention particulière aux spécifications et au coût des matériels de terminal.

RESUMEN

En este artículo se trata con cierto detalle de un sistema de comunicaciones digitales de gran velocidad, en que se emplea un satélite para entrelazar varias redes locales con diversas facilidades de computador. Se indican las ventajas de las comunicaciones por satélite en relación a los enlaces terrestres, junto con una investigación histórica del empleo de Satélites de Pruebas Orbitales (OTS) para experimentos en transmisión de datos y la participación de Marconi Communication Systems en estos experimentos.

Se da una descripción del Proyecto UNIVERSE, que es el más reciente empleo de OTS, indicándose la finalidad del proyecto y dándose una descripción más detallada de los elementos que componen la red, tales como los terminales terrestres del satélite, anillos de comunicaciones y enlaces terrestres.

Además de la descripción del programa para el Proyecto UNIVERSE y su finalidad, se consideran en el artículo los futuros desarrollos de estos sistemas y su aplicación en las comunicaciones comerciales. Se trata en particular de los factores que afectan a su crecimiento, poniéndose de relieve las especificaciones y los costos de los equipos terminales.

ZUSAMMENFASSUNG

Dieser Aufsatz befasst sich eingehend mit einem digitalen Hochleistungs-Nachrichtensystem, bei dem ein Satellit zum Verbinden mehrerer aus verschiedenen Computerfunktionen aufgebauten Ortsnetzen eingesetzt wird. Die Vorteile eines Satelliten gegenüber erdgebundenen Übertragungsstrecken werden im Einzelnen erörtert im Zusammenhang mit einer geschichtlichen Übersicht der Anwendung von OTS – Orbital Test Satellite – (Raumbahn-Prüfsatellit) bei Datenübertragungsversuchen und dem von Marconi Communication Systems bei diesen Versuchen geleisteten Beitrag.

Das Projekt UNIVERSE, die jüngste Anwendung von OTS, sowie der Zweck des Projekts wird beschrieben unter eingehender Betrachtung der das Netz darstellenden Elemente, wie z.B. Satelliten-Erdstationen, Nachrichten-Ringleitungen und Erd-Übertragungsstecken.

Ausser der Beschreibung des Projekts UNIVERSE, seinem Zweck und seiner Funktion, untersucht der Aufsatz die künftige Entwicklung solcher Systeme und deren Anwendung zum geschäftlichen Nachrichtenverkehr. Im Einzelnen werden die das Wachstum beeinflussenden Umstände betrachtet, insbesondere die Spezifikationen und Kosten der Endstationen.