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Use of Low Orbital Satellite Communications Systems for Humanitarian Programs

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INTRODUCTION

Communication and information exchange play a decisive role in progress and social development. However, in many parts of the world the communications infrastructure is inadequate and the capacity for on-line exchange of information may not exist. This is true of underdeveloped countries, remote and relatively inaccessible regions, sites of natural disasters, and of all cases where the resources needed to create complex communication systems are limited. The creation of an inexpensive space communications system to service such areas is therefore a high priority task.

In addition to a relatively low-cost space segment, an inexpensive space communications systems requires a large number of ground terminals, which must be relatively inexpensive, energy efficient (using power generated by storage batteries, or solar arrays, etc.), small in size, and must not require highly expert maintenance. The ground terminals must be portable, and readily deployable.

Communications satellites in geostationary orbit at altitudes of about 36,000 km are very expensive and require complex and expensive ground stations and launch vehicles. Given current technology, it is categorically impossible to develop inexpensive satellite systems with portable ground terminals using such satellites.

To solve the problem of developing an inexpensive satellite communications system that can operate with relatively small ground stations, including portable terminals, we propose to use a system with satellites in low Earth orbit, at an altitude of 900-1500 km. Because low orbital satellites are much closer to the Earth than geostationary ones and require vastly less energy expenditure by the satellite and ground terminals for transmission of messages, a system using them is relatively inexpensive. Such a system could use portable ground terminals no more complex than ordinary mobile police radios.

Between 1967 and 1989 the Scientific Production Association for Applied Mechanics and the Scientific Production Association for Precision Instruments gained experience in and developed technology for creating such satellite communications systems using COSMOS series low orbital satellites. This expertise and technology may be used to create inexpensive multisatellite communications systems.

CONCEPTUAL DESIGN OF THE SYSTEM

The inexpensive multisatellite communications system to be developed will utilize low-orbital satellites at altitudes of 900-1500 km. Information will be transmitted by the ground terminals to a satellite when it is in their coverage area, stored in memory, and then transmitted to its destination point (which may be located at any point on the globe) when the satellite flies over it. Thus the system operates according to the "electronic mail" principle.

A low orbital satellite may fly over a given point on the Earth's surface several times a day for a mean period of 8 minutes. Thus, if only a single satellite is utilized, a user needing to transmit or receive information would have to wait for on the order of several hours. Although such communication does not take place in real time, it nonetheless represents an enormous improvement in servicing of remote regions where delivery of message previously may have taken many days or even weeks. User service time may be significantly decreased by increasing the number of satellites in the system (system extension), while in the future relaying of messages between satellites will reduce the waiting period to close to real time.

It should be noted that within the coverage area of the satellite (diameter of the footprint is on the order of 5000 km) messages may be transmitted in real time.

Since low-orbital satellites are much closer to the Earth than geostationary satellites (by no less than a factor of 10), the ground terminals and satellites have less stringent energy requirements for transmitting messages (savings of no less than 20 db). This makes it possible to use small, portable, and inexpensive ground terminals, which may be powered by solar and storage batteries. For such a system, the following major design principles must be followed:

- Satellite and ground terminal antenna systems must be semidirectional.
- It is essential to use low frequency wave bands allotted to mobile communications, which improve the energy efficiency of the radio lines when semidirectional antenna are used.
- "Packet radiocommunications" technology, which minimizes the energy consumption of the satellite and ground terminals, should be used for communications.

- For efficient energy use by the satellite and ground terminals, modern signal level protocols should be used: phased (noncontinuous) methods for transmitting information, packet coding, and Weatherby decoding.
- The "electronic mail" message transmission mode is possible only if signals are completely demodulated on the satellite and stored for subsequent transmission to the user.

SERVICES PROVIDED

An inexpensive multisatellite communications system can transmit any data in digital form—telex, text, image, speech, exchange of information between databases or computers, and acquisition of data from environmental monitoring devices.

Messages may be transmitted in two modes. The "electronic mail" mode involves storage of messages in the satellite's memory and subsequent transmission to a user, when the sender and receiver are not in the satellite's coverage area at the same time. In the second mode the message is transmitted in real time. In this case the sender and receiver of a message must be in the satellite's coverage area simultaneously.

There are several possible variants of user ground terminals, depending on how they are to be are utilized. In remote relatively inaccessible regions, where there are no means of ground communications, users will have direct access to the satellite through portable ground terminals in which information is input (and output) through a special device or personal computer. In regions where there are means of ground communications, access to satellite communications will take place through regional stations, which will "concentrate" the messages and organize their exchange between system users using ground communications lines and with the satellite using radio lines. Given this type of organization, many thousands of users from any point on Earth will be able to transmit short messages in a fixed format (portable ground terminal) or messages consisting of many pages of text in A4 format (stationary ground terminals or regional ground stations).

An inexpensive multisatellite communications systems would have the following areas of application:

- Communications on a global scale with users located in remote and relatively inaccessible regions with poorly developed communications infrastructure
- Transmission of emergency messages and coordination of rescue operations in areas affected by natural disaster
- Collection of ecological information from tended and nontended environmental status monitors on the ground
- Access to databases and communications lines of the "computer-computer" type

- Transmission of medical information
- Exchanges of business information for economic development.

In conclusion, it may be said that the creation of the "Gonets" system would be an important contribution made by the "Smolsat" association toward the development of a global community and the solution of problems in disaster medicine. The use of the technical expertise and capabilities of the Applied Mechanics and Precision Instruments Scientific Production Associations will make it possible to create the system at an accelerated rate with the least possible expense.

The major capabilities and technical specifications of the system and its components are described in the attachment to this report.

ATTACHMENT

"GONETS" MULTISATELLITE COMMUNICATIONS SYSTEM

Applied Mechanics Scientific Production Association

Precision Instrument Scientific Production Association

GOALS:

- Creation of an inexpensive space communications system
- Ground terminals must be portable, serviceable by nontechnical personnel, and inexpensive
- Rapid deployment of the system in emergencies
- Use of the system must be simple and inexpensive
- Support global communications, including polar regions, and a large number of users.

NOTE: Satellites in geostationary orbit (orbital altitude of 36,000 km) are very expensive and require expensive equipment for orbital injection, ground stations, and use. At present these satellites cannot form the basis for creation of an inexpensive satellite communications system with portable ground terminals.

BASIC PRINCIPLES:

- A system of low-orbital satellites will be used (orbital altitude of 1300 km-1500 km) (savings in energy compared to geostationary orbits of no less than 20 dB)
- Antenna systems of the satellite and ground terminals must be weakly directional (they will not be need to be pointed at each other)
- Frequency bands:
  1. 312-315 MHz (uplink), 387-390 MHz (downlink)
  2. 1642.5-1643.4 MHz (uplink), 1541.0-1541.9 MHz (downlink).
- Packet radiotechnology (minimizes energy consumption of the satellite and ground terminals)
- Advanced signal level protocols
- Phased methods of transmission, packet coding with Weatherby decoding (economy of energy consumption by the satellite and ground terminals)
- Complete processing (demodulation, decoding) of signals on the satellite and their storage for organization of the "electronic mail" mode of operation and energy savings.

SERVICES PROVIDED:

- Transmission of any data in digital form—telex, text, image, speech, exchanges of information between databases and computers, collection of data from environmental monitoring devices.

MODES:

- Electronic mail—with storage in the satellite's memory and subsequent transmission to the user (the sender and receiver not in the coverage area of a satellite at the same time)

- In real time (sender and receiver are in the coverage area of a single satellite at the same time).

MODERNIZATION:

- Introduction of intersatellite communications lines—enabling real-time transmission of information in all cases.

AREAS OF USE:

- Global communications with users located in areas with poorly developed communications infrastructure

- Transmission of emergency messages and coordination of work in areas of natural disasters

- Collection of ecological information

- Exchange of information between databases and communications of the "computer-computer" type

- Exchange of scientific and educational information

- Transmission of medical information

- Exchange of business information for economic development.

USER ACCESS:

- Direct access through a portable terminal equipped with an I/O device or personal computer

- Through ground communications lines, regional station (information concentrators).

SPACE SEGMENT:

Circular polar orbits (inclination 83°) altitude 1300 km - 1500 km

Six planes of six satellites each. The planes are separated from each other by 30° along the longitude of the ascending node

Group launch of six satellites at a time

Mean waiting time for a communications session no greater than 20 minutes, with probability 0.8

Orbital structure was selected under the assumption of homogeneous rate of traffic over the surface of the Earth (homogeneous servicing of the entire Earth), and minimization of the number of satellites. The orbital inclination was selected with consideration of existing launch trajectories.

NOTE: If traffic is no homogeneous over the surface of the Earth the orbital structure would be altered.

COMMUNICATIONS STRUCTURE

Marker signal for determining the presence of the satellite in the radiovisibility zone contains information for establishing communications: number of the satellite, nominal frequency, computation of temporal position for organization of scanning

Modes of operation: packet and data transmission.

Up- and downlinks will have three frequency channels each:

in the 300/400 MHz band:
data transmission channel 9.6 kbit/s
signaling channel—(4.8-9.6) kbit/s

in the 1.5-1.6 GHz band:
data transmission channel—64 kbit/s

Access protocol:
signaling channel—ALOHA
data transmission—as required.

Delivery of information: uncontrolled with addressing in the marker signals, information routed through the relay control center (up to 3 hours delivery time).

Number of users—up to 1,000,000

System capacity:
1.5/1.6 GHz - $2.5 \cdot 10^4$ Mbit/day or $2.5 \cdot 10^6$ pages in A4 format per day
300/400 MHz - $1.85 \cdot 10^3$ Mbit/day or $0.18 \cdot 10^6$ pages in A4 format per day.

SPACECRAFT:

Magnetic-gravity system of orientation (one axis) with accuracy of 5-10 degrees

Passive thermoregulation system with electric heater will provide a temperature of 0-40° C

Electric power system: solar arrays and nickel hydrogen storage battery—supports mean consumption per orbital pass of 45 W, 160 W per session

Communications antennas will be semidirectional with enhancement coefficient of 0-3 dB

Mass—225 kg

Group orbital injection of six spacecraft at a time.

RELAY:

Mass—60 kg

Rate of information transmission—4.8 kbit/s, 9.6 kbit/s, 64 kbit/sec

Capacity of on board memory—8 Mbytes (5000 pages in A4 format)

Working life—3-5 years, the spacecraft provides backup

Power of the transmitter—2-10 W

Noise temperature of the receiver—200° K

Mean energy consumption per orbital loop—45 W

Complete processing of signals, digital complex is programmable.

USER TERMINALS:

AT-M: Small, portable terminals:
Mass—1-3 kg
Power of the transmitter—2-5 W
Noise temperature—200° K
Station supplied with an IO device
Power - storage batteries

AT-S: Stationary terminals
Mass—60 kg
Transmitter power—5-10 W
Noise temperature—200° K
Personal computer
Power from storage battery and from an alternating current network.

REGIONAL STATIONS:

Mass—5- kg

Power of transmitter—50 W

Noise temperature—150°K

Personal computer

Device for linkage with ground data transmission lines

Power from alternating current network