SPACE SATELLITES AND WORLD COMMUNICATIONS*

DURING the post-war period rapid growth in the facilities for world communication using transoceanic telephone cables has appeared as technically possible. Just recently this has been followed by proposals for radio repeater stations in space satellites providing cheap and unlimited communication facilities on an even greater scale. The subject has more than engineering importance.

The artificial satellite which communication engineers propose to use as a means of expanding world communications will act as a repeater station in space, having a line-to-sight path to the earth stations with which it communicates. Because radio communication will no longer depend on reflection from the ionosphere it will be possible to use that part of the radio spectrum between about 1000 and 10,000 Mc./s. This has a communication capacity several hundred times that of the H.F. band at present used.

Passive Satellites

The most elementary form of communication satellite consists of a simple reflector travelling round the earth at a height of a few thousand miles. President Eisenhower used a satellite of this kind to deliver a Christmas message in 1958. A more serious test of the feasibility of relaying radio signals over long distances by 'bouncing' them from passive reflecting surfaces was made in 1960 when the United States National Aeronautics and Space Administration (NASA) put a 100 ft. diameter metallized plastic balloon into orbit at a height of about 1000 miles. This was known as the ECHO balloon and was used to reflect telegraph, telephone and facsimile signals transmitted between a NASA station in California and the Bell Telephone Laboratories at Holmdel, New Jersey.

Even when highly directional antennas are used on the ground, only a very small proportion of the energy radiated by the transmitter will hit a passive satellite and an even smaller part will be reflected back and dispersed over the earth's surface. Because of this, very high power transmitters would be needed to achieve communications using passive satellites at heights of interest. It is not only difficult to generate this high power at microwave frequencies but a transmitter of the power required would give rise to considerable interference. For this reason active satellites are more likely to be used for communication purposes. They will contain electronic repeaters which will amplify the received signals before re-transmitting them back to earth.

Active Satellites

The kinds of active satellite which have been most discussed are:

(1) Satellites in circular orbits at heights between 2,000 and 6,000 miles. Each will complete a circuit of the earth in 3 to 8 hours and appear to move fairly rapidly across the sky. A number will be required that at least one is always visible to both terminal radio stations.

(2) Satellites in circular equatorial orbits at a height of 22,300 miles. At this height a satellite makes one rotation every 24 hours and therefore appears stationary relative to a point on the earth's surface.

An American proposal of the first kind would employ 50 satellites at a height of 3,000 miles to provide world-wide communication. The satellites are divided into three sets in orbits making angles of 60° with each other. A variant of this, suggested in the United Kingdom, is for the use of satellites in elliptical orbits with perigees 300 miles high and apogees from 10,000 to 12,500 miles. Provided the orbits can be maintained in their relative angular positions, 12 satellites would provide complete global coverage.

All low-orbiting satellites, active or passive, require steerable transmitting and receiving antennas on the ground which can be continuously directed on to them. Dishes, 60 or 80 ft. in diameter, will probably be used. In a commercial system these would have to be duplicated at each ground-station in order to prevent interruption of communications during the period when one satellite is beginning to pass out of view and another taking its place as the communication link. Because of the, desirably, very narrow beamwidth of the ground-station steerable antenna, automatic tracking of the satellite will be necessary. This will be controlled by a signal returned from the satellite.

The second kind of proposal which makes use of satellites with an orbital period of 24 hours has a number of obvious advantages. At this height a satellite will 'look-at' nearly half the earth's surface and only three such satellites

* From the Presidential Address of Sir Gordon Radley, K.C B., delivered to Section G (Engineering) on August 31, 1961, at the Norwich Meeting of the British Association. By courtesy of the B.A.A.S.

would be required to provide for communication between any two points on the earth's surface.

Because the satellite will remain stationary relative to the transmitters and receivers with which it communicates, the design of the ground-station equipment is simplified. On the other hand, the distance of about 45,000 miles which the radio signals have to traverse in a trip, ground-satellite-ground, introduces a delay of 240 milliseconds into their transmission, or about a half-second before a reply can be received. For the transmission of telegraphy data, television and many other kinds of communication this does not matter. Communication engineers are as yet uncertain whether delays of this order would be troublesome in a telephone conversation.

Satellite Power Sources

Power to operate the electronic equipment in an active satellite will be obtained initially from the sun although the long-term development of light-weight nuclear sources must not be ruled out. Much work has been done during the last 5 years on the development of the solar cell, principally by the Bell Telephone Laboratories in the United States. Although the cell, in its present form, is not yet satisfactory for long-term service in a satellite, it seems reasonable to plan on the assumption of its use in the future.

The solar cells may be supported on 'sails' at the sides of the satellite, extended after the satellite has settled in its orbit. They will have to provide an area of one or two square yards in order to generate enough power to operate the radio transmitter. During the time that a satellite is in the shadow of the earth, power will have to be supplied from storage batteries.

Satellite-to-Ground Transmission

Satellite communication systems will make use of frequencies in the same part of the spectrum as entirely ground-based, radio-relay systems. But the distance between relay stations in a land system is usually about 40 miles compared with 4,000 or much more to the satellite. Moreover, on land, highly directional transmitting and receiving aerials enable signals to be beamed from station to station. Highly directional aerials are almost impossible to arrange on a satellite and, in order to make use of any directivity, it is necessary to maintain altitude control of the satellite.

Taking both the increased distance and the lack of directivity together, the transmission loss between a communication satellite and its ground station may be 80 dB—100 million times on a relative power basis—greater than the loss between two adjacent stations in a land radio relay system.

The problem is not serious in the direction ground-to-satellite because high transmitting powers can be used, fed into large parabolic antennas directed on to the satellite. It is serious in the other direction because the power of the transmitter in the satellite is limited to 1 or 2 watts and the signals it sends out are dispersed over a very large part of the earth's surface.

Amplification of these weak signals by means of a device which itself has very low intrinsic noise is the nub of the problem. Because of the thermal agitation of its molecules, every element of an electrical circuit produces spontaneous unwanted noise signals at radio frequencies. It has become common to measure this noise in terms of the equivalent temperature of its source; for a conventional amplifier this may correspond to 3000° K. The invention of the 'maser' provided the engineer with low-noise amplifying devices of a new kind. Taking advantage of the principles of quantum mechanics, a very weak incoming signal is able to trigger a great amount of power over a limited frequency range. The problem generally is to extend this range, but 'masers' have been constructed with a frequency coverage adequate for a satellite communications system.

Modulation Methods

The economics of satellite communication suggest planning in terms of at least 600 two-way telephone channels, or one two-way television channel. It remains necessary to mention the way in which the messages will be impressed on the radio signal. Information theory tells us that by increasing the transmitted frequency band, it is possible to improve the signal-to-noise ratio without increasing transmitter power. Frequency-modulation is a technique frequently used for this purpose. Pulse-code modulation, in reality a method of processing information before applying it to any type of radio transmission, has many attractions. The important feature of both is their relative freedom from interference but fairly wide bandwidths are required and it is likely that at least 250 Mc./s. will be needed by each satellite system for two-way communication on the scale envisaged.