Using the

OSCAR III V.H.F.

Communication

Satellite

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OSCAR III, the third in a series of space communication satellites designed and built by radio amateurs, is being tested in a preflight prototype package in preparation for a launch during the winter months of 1964. The Oscar III satellite is a battery-powered high-frequency *translator*[1] operating in the internationally assigned 2-meter band (144-146 Mc.) in accord with the new amateur space allocation granted at the recent ITU Space Communications Conference held in Geneva.[2]

In brief, the Oscar III satellite permits two-way v.h.f. communication to be achieved by radio amateurs separated by the curvature of the earth (Fig. 1). The main portion of the transistorized equipment in the satellite listens to a 50-kc. segment of the 2-meter band centered about 144.1 Mc. and instantaneously translates this portion of the spectrum to a 50-kc. segment centered about 145.9 Mc., retransmitting the latter band segment to the ground observer. The

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[1] Orr, "The Oscar III V.H.F. Translator Satellite," *QST*, February, 1963.

[2] Jacobs, "Amateur Radio and the ITU Space Communications Conference," *CQ*, January, 1964; "The Geneva Space Conference," *QST*, January, 1964.

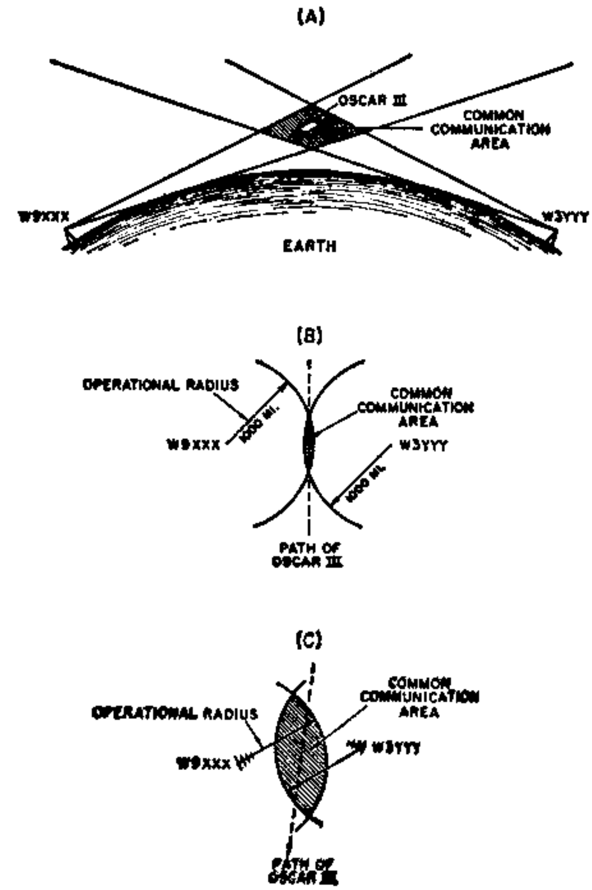


Fig. 1—(A) A common communication area exists between two v.h.f. stations communicating via Oscar III. The area depends upon the distance between the two stations and the operational range of each station.

(B) Two v.h.f. stations within 2000 miles of each other are theoretically able to communicate via Oscar III if the satellite orbit is about 120 miles above the surface of the earth. At such extreme range, however, the satellite traverses the common communication area in a matter of a few seconds

(C) As Oscar III will probably have a north-south (polar) orbit, stations located on an east-west line will generally have a longer communication time than stations on a north-south line. The length of time Oscar III remains in the common communication area depends upon the distance between the stations and the angle the satellite cuts across the area.

satellite runs continuously, and an operational life of about one month is expected before the batteries expire. It is an aim of the Oscar Association eventually to launch a repeater of a similar nature with a higher orbit and longer operating life.

In addition to the wide-band translator, Oscar III will incorporate two beacon transmitters. The first beacon will transmit on 145.85 Mc., and the signal will be the well-known Oscar "HI" sent in Morse Code, followed by a burst of telemetering. Three separate measurements will be made within the satellite package and a simple system of pulse-width modulation will telemeter this information in sequence. The ground observer will be able to interpret the telemetered information with the aid of a 2-meter receiver and an inexpensive oscilloscope.

The second Oscar III beacon will transmit a continuous unmodulated signal on 145.95 Mc. and will be useful for those experimenters wishing to make experiments requiring a phase-coherent signal. The two beacon signals will bracket the 50-kc. spectrum which contains the output from the translator (Fig. 2).

Operational Range of Oscar III

The operational range of Oscar III depends, among other factors, upon the height of orbit above the earth. As this is unknown at the present time, it will be assumed to be about that of the earlier Oscar satellites (approximately 120 miles) until proven otherwise. Based on this figure and upon experience gained with Oscars I and II, a radius of ground reception of the satellite turns out to be *about* 1000 miles. Thus, two stations within 2000 miles of each other are theoretically just within communication range via Oscar III (Fig. 1B). At this distance, however, contact would be problematical, as the common communication area for both stations is extremely small. Stations 800 miles apart or less, however, stand a much better chance of communication as the satellite remains within the common communication area for a greater length of time. Stations located along an east-west line, moreover, will generally have longer common communication time, as the Oscar III satellite will probably have a north-south (polar) orbit. The length of time the satellite remains within a common communications area between two stations depends upon the distance between the stations and the angle at which the satellite cuts across the area. For short-distance contacts (stations separated by 500 miles or less, Fig. 1C) the satellite traverse time across the common communication area may be as much as six to eight minutes, whereas for extreme distances the traverse time may be a matter of only a few seconds.

Using Oscar III

Various types of experiments may be conducted by radio amateurs during the forthcoming flight of Oscar III. Passive, "listening experiments" are useful, as well as attempts to achieve two-way v.h.f. communication via satellite. In all cases, however, it is well to plan the operation in advance so that valuable time will not be lost during the period that the satellite is within radio range, estimated to be about eight minutes or less.

Telemetering Measurements: A more sophisticated form of telemetering is incorporated in Oscar III than was used in the first two amateur space satellites. The original Oscar beacon telemetered internal package temperature to earth by means of a temperature-sensitive element that varied the "HI" rate in such a way that a simple count of the rate by the ground observer could be translated into package temperature. The "HI" rate of Oscar III will be nearly constant and used only as an identifier, broken regularly by bursts of telemetering. The telemetering will consist of a series of pulses whose width will be a measure of the transmitted intelligence. Observing the ratio of pulse width to repetition rate on an inexpensive oscilloscope will provide temperature data. Several thermal points will be monitored within Oscar III and the measurements will be transmitted in sequence, as will be described in a future article. The Oscar Association requests temperature measurement reports by interested amateurs during the forthcoming flight.

Doppler Measurements: The 145.95-Mc. beacon may be used for Doppler data [3] by ground observers. The beacon emits a continuous, unmodulated signal, suitable for long-term measurements. It is hoped that some observers will maintain a 24-hour watch on this beacon, as various observations made on Oscar II point to unusual modes of propagation that permit extremely long distance reception of the satellite, well beyond the usual line of sight. A continuously-running receiver coupled to a tape recorder may very well turn up a permanent record of long-distance reception by as-yet-unexplained modes of v.h.f. propagation. In addition, Doppler measurements may be made on this beacon to determine orbital parameters and predictions of future passes.[4]

[3] Norgaard, "Eyeball and Eardrum Doppler Tracking," *QST*, April, 1962 and June, 1962.

[4] Burhans and Rankins, "Keeping Track of Oscar," *QST*, May, 1962. Hilton, "Making Your Own Orbital Predictions from Doppler Measurements," *QST*, March, 1962.

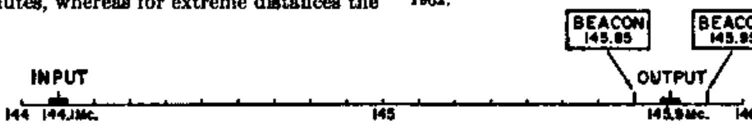
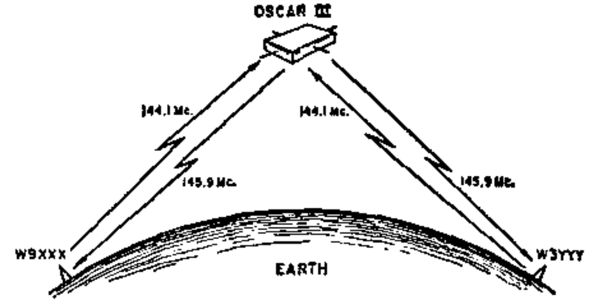


Fig. 2—The 2-meter spectrum of Oscar III. The 50 kc. input band of the satellite is centered about 144.1 Mc. The corresponding output band is centered about 145.9 Mc. (inverted). Beacon transmitters are on 145.85 Mc. and 145.95 Mc., bracketing the output band.

Fig. 3—Oscar III translates a v.h.f. signal from 144.1 Mc. to 145.9 Mc. Signals may pass both ways simultaneously through the repeater, which operates continuously during the life of the battery. Oscar III inverts the received signal so that the transmitted sidebands are reversed within the satellite, thus reducing the combined Doppler shift to a value never greater than that observed by a simple one-way satellite-to-earth transmission.



Passband Monitoring

The translation equipment in Oscar III will run continuously. When the satellite is in a quiescent state (no signals being received) the output of the translator consists of circuit and received noise, and may be readily identified by the ground observer as a hiss or "white noise" which covers the 50-kc. output frequency spectrum. The satellite may, in fact, be readily identified by this unique noise. When a v.h.f. signal of sufficient strength to activate the a.g.c. system of the satellite falls within its input passband, the output noise drops and the translated signal may be heard by a ground observer monitoring the output range of 145.875–145.925 Mc. As the satellite passes by, ground observers may tune back and forth across this range, logging signals within the passband that are repeated by Oscar III. Even though the observer possesses no transmitting equipment he will be capable of making a valuable contribution to the Oscar program by monitoring the passband and logging all signals heard within the band. Copies of such logs should be sent to Project Oscar, Inc., Box 183, Sunnyvale, California, U.S.A.

It should be noted that signals passing through the translator portion of Oscar III and received on earth will be subject to a Doppler shift occuring over two different paths. That is, the received signal will be a victim of Doppler shift as a result of the two-way transmission inherent in this system (Fig. 3). The translation circuitry of Oscar III inverts the received signal so that the transmitted *upper* sideband of a ground transmitter will be repeated back as the *lower* sideband to a ground observer. This is done to reduce the combined Doppler shift to a value never greater than that observed by a simple one-way satellite-to-earth transmission.

It is possible, of course, that nearby ground-based signals occupying the satellite output frequency range may cause interference with the repeated satellite signals. It is hoped that radio amateurs will stay clear of the Oscar III output frequencies during the pass time in a given location. Nontranslated earth signals in the output passband may be hard to identify although they will have no Doppler shift. Satellite-repeated signals generally will exhibit some degree of Doppler shift, but this may be less than the frequency drift commonly seen with many v.h.f. rigs using overworked surplus crystals!

Two-Way Satellite Communication

The primary purpose of Oscar III is to permit two-way radio amateur translator satellite communication beyond the normal v.h.f. range. Maximum communication distance is limited by the orbital height of the satellite, which will be unknown until after launch, but it is hoped that transcontinental or transoceanic contacts may be had by well-prepared radio amateurs. Experiments conducted by amateurs living in the San Francisco area with a preliminary Oscar III model, mounted atop a tower at the home of W6VMH, proved that the satellite permitted satisfactory two-way communication *provided* the users knew what they were doing and coordinated their efforts. Many of the users of the earth-bound Oscar repeater during this preliminary test were Oscar Association members, well versed in the working of the equipment, yet the thrill of the moment and the excitement of using a spectrum repeater led to chaos, confusion and unwanted interference until some form of discipline was planned in advance and a method of use established. It must be remembered that the output power of Oscar III, approximately one watt, will be shared by all the signals passing through the repeater. As more signals pass through Oscar III at one time, a point will be reached where each signal commands such a small part of the available output power that none of the signals is usable by the ground observer. The output spectrum of the satellite then becomes a confused, mumbling mass of "garbage." This may be expected to occur within range of areas of heavy v.h.f. population during week ends when many stations may try to use the repeater. At other times, only a few signals will pass through the repeater as it orbits over other areas of the world.

One suggested means of making optimum use of the Oscar III repeater is to take advantage of the "buddy" system. This requires two amateurs to act as a team, with a predetermined operation sequence, or "script." A joint effort will help to ensure that when Oscar III appears over the radio horizon an attempt at two-way communication may be made under circumstances that will encourage success.

For illustration, let us assume a hypothetical pass of Oscar III between two v.h.f. stations that desire to achieve two-way satellite communication. The problem is defined in this manner:

1. When does the satellite approach the proper position between the two stations, and how long will it remain within radio range of both stations?
2. What will be the line of position of the satellite between the stations as it moves along its orbital path?
3. What should be the transmitting frequency of each station, and to what frequency should each station receiver be tuned in order to hear the satellite-repeated signal of the other station?
4. At what critical times will each station listen and transmit?

It would be reasonable to assume, until proven otherwise, that calling CQ at random and "looking across the satellite band" for a contact would be asking too much; at least until the would-be satellite DXer has experience gained in a prearranged schedule with a reliable, not-too-distant v.h.f. companion. The greatest chance of success would seem to stem from a predetermined sequence of operation enacted between two coordinated "buddy stations" who have practiced their *modus operandi* aided, perhaps, by pre-launch low-frequency coordination schedules or by mail.

The Oscar Association emphasizes that Oscar III experiments in two-way communication differ in one important respect from other v.h.f. communication experiments conducted in the past by radio amateurs. Previous long-distance communication efforts based on propagation anamolies depended heavily on chance or luck for success. If the atmospheric diffraction was right; if the microwave duct was established; if the signal scattering was effective; if the unknown mode of propagation worked — the fleeting two-way contact was established on a hit-or-miss basis. Hours (or years) of work, largely with unknown, random factors, contributed to success.

This heuristic (cut-and-try) philosophy is absent in Oscar III. If launch is successful and the satellite equipment functions properly, alert radio amateurs using the proper operating techniques and equipment at the proper time and frequency can achieve two-way repeater communication. Propagation anamolies have little to do with it; Oscar III is a "go, no-go" bird and affords predictable success to those amateurs using it in a knowledgeable fashion. Communication via Oscar III is not something you *try*, it is something you *do*!

The Oscar Association will do its utmost to provide accurate and up-to-date tracking information. In addition, v.h.f. amateurs and clubs who tracked the earlier Oscar satellites are urged to generate and disseminate their own tracking information for local consumption.

A QSO Via Oscar III

By way of example, let's eavesdrop on a hypothetical 2-meter QSO via Oscar III. Remember, one of these stations may be *you!* Our two heroes are W9XXX in central Illinois, and W3YYY in western Pennsylvania, situated about 500 miles apart, on an east-west path. Each station is equipped with a stable, low-noise 2-meter receiver, accurately calibrated in kilocycles across both the input and output ranges of the Oscar III satellite. In addition, each station is equipped with an auxiliary "early-warning" receiver, tuned to 145.95 Mc., the c.w. beacon frequency, or to 145.85 Mc., the telemetry beacon frequency.[5] The receivers may consist of two v.h.f. crystal-controlled converters feeding a stable low-frequency communications receiver.

Each station is equipped with a 100-watt output crystal-controlled 2-meter transmitter, the frequency of which is known to a kilocycle. In addition, each station has a medium-gain Yagi antenna (5 elements, approximating 10 decibels) rotatable in azimuth only, controlled by a second operator whose job is to keep the beam antenna aimed on the satellite by virtue of the early-warning receiver tuned to a satellite beacon signal.

Information from the Oscar Communication Center has notified our two DX-perts that the satellite will pass approximately between them, on a north-south path during the time period of 1400–1417 GMT. The tactical situation is shown in Fig. 1C. W9XXX aims his antenna to the east of north, and W3YYY aims his antennas to the west of north.

Both stations have agreed beforehand to transmit on 144,110 kc. plus or minus one kilocycle. They know that the Oscar III translator will invert their signals and retransmit them back to earth on 145,890 kc., ten kilocycles lower than the center frequency of the output range. Initially, it is decided that W9XXX will start transmitting when he first hears the beacon signal, while W3YYY will listen for W9XXX at the proper satellite repeated frequency of 145,890 kc. As a starter, therefore, the early-warning receiver of each station is tuned to the satellite beacon frequency of 145.85 Mc. and the communication receiver is tuned to 145,890 kc. As the fateful hour approaches when Oscar III comes within range, the two stations quickly run through their individual "scripts":

1. Clock properly set to GMT? Yes.
2. Communication receiver tuned to 145,890 kc.? Yes.
3. Early-warning receiver properly tuned to 145.85 Mc.? Yes.[6]
4. Antennas positioned in the proper direction? Yes.
5. It is known that Oscar III will approach the common communication area at 1400 GMT on each station's clock, and it is agreed that W9XXX will start transmitting as soon as he hears the beacon. Since he knows that W3YYY will hear the beacon at almost the same instant, he has decided to transmit for 30 sec-

[5] In this article, satellite frequencies are given in megacycles, and ground station frequencies are given in kilocycles.

[6] In this type of short-distance pass, with the satellite between the stations, the over-all Doppler shift through the translator will be very small.

onds, then he will listen for one minute at 145,890 kc.

Each station is ready. The growing tension is broken by the second operator at W9XXX announcing he has heard and identified the c.w. beacon of the satellite! The tape recorder is started, and a few seconds later, reception of the beacon is verified at W3YYY. The time for the record-breaking QSO is at hand! According to the prearranged plan, W9XXX starts to transmit, calling W3YYY on 144,110 kc. with slow, steady c.w., one eye on the GMT clock. Five-hundred miles to the east, the second operator of W3YYY tracks the satellite beacon while the first operator tunes a few kilocycles above and below the repeater frequency of 145,890 kc. He hears the "white noise" of Oscar III, and carefully listens for the c.w. signal of W9XXX retransmitted back to earth via the space craft! Success is almost at hand when he finally hears a portion of W9XXX's transmission, clearly audible above the "white noise"!

When the 30 seconds are up, W9XXX signs over and starts to listen near 145,890 kc. for W3YYY, while the second operator at W9XXX faithfully continues to track the satellite beacon with the early-warning receiver, making any necessary adjustments to the beam antenna to hold the beacon signal at maximum strength. W3YYY is calling W9XXX on c.w., and shortly, the operators of the latter station are thrilled to hear the translator-repeated signal of W3YYY calling them close to 145,890 kc.! W3YYY passes a signal report to W9XXX and the QSO starts to resemble a normal low-frequency contact. Finally, during W9XXX's reply, both second operators note that the satellite beacon signal is going out of range, and sure enough: contact between the two stations is abruptly lost as Oscar III dips below the radio horizon. The first QSO via Oscar III satellite has been successfully completed! The record-making QSO, moreover, has been recorded on tape at both stations and has become a permanent record of the unique accomplishment.

This, then, is one way the first contact via Oscar III may be expected to be made. No doubt, sooner or later, some amateur will call CQ and receive an answer at random via the satellite. It is hoped, moreover, that trans-oceanic and trans-continental QSOs will be achieved by this unique repeater satellite. As this is the first time such an experiment has been undertaken, all prophesies and predictions are, of course, based upon intelligent guesswork and may prove to be invalid. The possibility exists that the satellite may be badly overloaded near areas of intense v.h.f. activity and remain silent but receptive over areas of the world where little v.h.f. activity is present.

Remote-area "Beacons"

It is hoped that amateurs in areas of the world having little v.h.f. activity will supply beacon signals that will activate the satellite to alert other, distant observers. A v.h.f. beacon transmitter in the Azores, for example, may activate Oscar III over the North Atlantic area so that such passes may be heard on both sides of the Atlantic. A similar beacon near the Fiji Islands and one near India will activate the satellite over Pacific and Asian areas.

It is readily apparent that this new adventure of amateur radio is a voyage into the unknown, and no member of the Oscar crew really knows all the answers, or has a complete picture of the capability of Oscar III. Surprises for all will be in store when Oscar III goes into orbit, and radio amateurs worldwide join Project Oscar in looking forward to a successful launch and an exciting and useful life for this 30-pound package of surprises.

Acknowledgement

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