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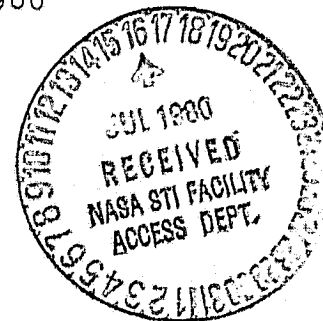

COMMUNICATIONS VIA THE "RADIO"
ARTIFICIAL EARTH SATELLITE: DESIGN
OF THE TRACKING DIAGRAM and FEATURES
FOR CONDUCTING QSO

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COMMUNICATIONS VIA THE "RADIO" ARTIFICIAL EARTH SATELLITE; DESIGN OF
THE TRACKING DIAGRAM

By V. Dobrozhanskiy, Laureate of USSR State Prize

General information of how to prepare for work through the transmitting   /17*
artificial earth satellite (construction of a tracking diagram) has already

been published in the journal Radio [1,2]. Now, when the real parameters of the

orbit of the radio amateur satellites "Radio-1" and "Radio-2" are known we will

examine this question more specifically.

We recall that these satellites are put into an almost circular orbit, close

to the polar. This orbit has the following parameters: period of rotation (T)--

120.4 minutes; inclination (i)--82.6°; height (H)--1,724 km at the apogee and 1,688

km at the perigee.

It is evident that the orbit is actually close to a circular, and for further

calculation we will consider that H=1,700 km. Error in determining the possible

time of communication to the AES [artificial earth satellite] governed by such

an approximation will be insignificant.

To predict the possible communications sessions it is necessary to construct

a tracking diagram for the AES. The most convenient for this is a map in the so-

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*Numbers in margin indicate pagination in original foreign text.

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called stereographic polar projection of the Northern Hemisphere (see second page of insert). The largest part of the continents, including the entire territory of the Soviet Union is located precisely in this hemisphere, and radio communication through the AES will be implemented mainly in limits of this hemisphere.

It is necessary to plot on this map the zone of maximum radio visibility from the given QTH. For this (figure 1) the greatest value of the geocentric angle α is computed (from the entrance to the exit of the AES from the zone of radio visibility) and the diameter of the "communications circle" D according to the following formulas:

$$\frac{\alpha}{2} = \arccos\left(\frac{r_0}{r_0 + H}\right),$$
$$\frac{D}{2} = \frac{2\pi r_0}{360} \cdot \frac{\alpha}{2},$$

where r_0--radius of earth (6,371 km).

For the orbit of the radio amateur satellite "Radio-1" and "Radio-2" we obtain $\alpha/2 = 37.9°$ and D/2=4,112 km. The values of these parameters will be such for any point of the earth.

One should note that the boundaries of the "communications circle" will be the circumference only with their plotting on a globe. With the use of maps with varying projection its precise shape to a greater or lesser degree will differ from the circumference. For maps with stereographic projection with accuracy that is completely applicable for solving practical tasks of amateur communications, the boundaries of the zone of maximum radio visibility can be reduced to the circumference.

This is done as follows. To the value of the geographic latitude φ of the given point we add and subtract the maximum value calculated above for the geocentric angle $\alpha/2 = 37.9°$. This yields us the northern (φ_n) and southern (φ_s) bound-
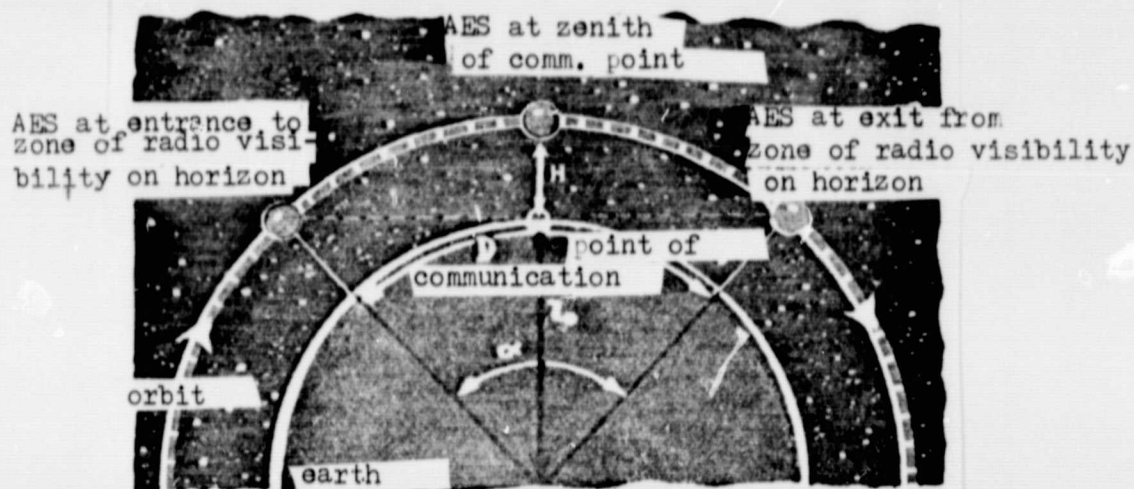
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Figure 1.

aries of the "communications circle." Then these points are plotted on the map

on the meridian of the communications point, and the distance between them is

divided in half. This will be also the center of the "communications circle."

From it a circumference is made that naturally passes through the points φ_n and

φ_s (see second page of the insert).

For example, for Moscow (latitude φ=55.6° n.l., and longitude λ=37.6° e.l.)

we obtain φ_n=93.5° and φ_s=17.7°. Since the coordinate for the latitude of the

northern point of the "communications circle" φ_n exceeds 90°, then this point will

be found already in the Western Hemisphere (on the continuation of the meridian

of Moscow for the North Pole) at latitude 86.5°. It is apparent that the center

of the circumference does not coincide with communications point (it lies to the

south of Moscow). However the zone of maximum radio visibility constructed accor-

ding to this simple technique will be close to the actual.

For an approximate determination of the direction of finding the AES on the route in the zone of radio visibility (this is important with the use of directional antennas) one should plot on the line of circumference of the zone the azimuths, having taken as 0° the point $\mathcal{T}_n$ on the meridian of the communications point (clockwise, for example, through 30°).

The next stage in constructing the tracking diagram is computation of the AES route.

The route is the name for the projection of the orbit of the satellite (geometric site of the subsatellite points) on the surface of the rotating earth. For each revolution of the satellite the route intersects the equator twice. Once during the transition of the AES from the Southern Hemisphere to the Northern, and the other during the transition from the Northern to the Southern. The point (value of longitude with respect to the equator) at which the satellite crosses from the Southern Hemisphere to the Northern is usually called the ascending junction of the orbit, the opposite transition—the descending junction.

As a result of the daily rotation of the earth with constant angular velocity 0.25° per minute, the passage of the route with each orbit is shifted to the west with respect to longitude by an amount $\Delta\lambda$=0.25° x T. For the satellite "Radio-1" and "Radio-2" (T=120.4 min) $\Delta\lambda$ will be 30.1°. The number of orbits that the satellite will make in a day will correspondingly equal N=360°/$\Delta\lambda$. For our case N=12.

The natural repetition of the route with each orbit and the constant amount of each shift ($\Delta\lambda$) make it possible to be restricted to constructing a reference route for one orbit. In our case it is sufficient to construct it only for half of the orbit in the Northern Hemisphere. The calculated data for the reference

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route for satellites "Radio-1" and "Radio-2" obtained according to the technique
that was published in the journal Radio [2] are given in table 1.

TABLE 1.

Time, min	ψ_R n.l.	λ_R e.l.
0,0*	0,0	0,0
4,0	11,8	0,6
8,0	23,7	1,3
12,0	35,5	2,4
16,0	47,3	4,2
20,0	58,9	7,6
24,0	70,3	15,6
28,0	80,2	42,9
30,1**	82,5	82,5
32,0	80,6	119,3
36,0	70,9	148,7
40,0	59,5	157,0
44,0	47,9	160,6
48,0	36,1	162,5
52,0	24,3	163,6
56,0	12,5	164,3
60,0	0,6	164,9
60,2***	0,0	164,95

Notes: *beginning of reference route
          **one quarter of revolution
          ***half of revolution

   In the first column of it the current time of flight of the AES (t) is indi-
cated, and in the two others—coordinates of the reference route ψ_r and λ_r. From
these coordinates one can construct on the map a reference route and set aside
on it the sections that equal 4-minute intervals of time.

   According to the generally accepted system of geographical coordinates the
longitude of the reference route is determined from the starting meridian (Green-
wich) to the west and east of zero to 180°, and consequently, requires the corres-
ponding indication of the western (w.l.) or eastern (e.l.) longitude, which is
not always convenient. Therefore in practice the system of reading the longitude
to one side, to the west of the starting meridian from zero to 360° is used. In
this case the values of longitude to the west of zero to 180° remain unchanged,
and in the transition to the eastern hemisphere conversion is required (360°-- $\lambda_{e.1.}$),

as this is done on the tracking diagram depicted in the insert.

On a tracking diagram, besides the zones of radio visibility for four cities (Moscow, Noril'sk, Vladivostok and New York) the dotted line plots 12 daily routes under conditions of the accepted longitude of the ascending junction of the first orbit 0°.

Now in order to determine the time of entrance of the AES into the zone of visibility it is necessary to add to the time of passage of the subsatellite point through the equator (ascending junction) the time shown on the reference orbit at the point of intersection of the route with the circumference of radio visibility. The duration of the communications session is defined as the difference in the time of entrance and exit from this zone of radio visibility.

For the first (conditional) orbit numbers with respect to time are plotted on the reference route, and it is easy to see that in this case for Moscow the satellite enters the zone of radio visibility roughly in 9 minutes after intersection of the equator and will be located in it for about 25 minutes. For Noril'sk these amounts will be correspondingly 20 and 24 minutes, and for Vladivostok-32 and 20 minutes.

Information on the ascending junction of the orbit are taken from the appropriate operational publications in which the number, month, year, ordinal number of the orbit, time of passage of the equator of the subsatellite point, and longitude of the ascending junction are indicated.

According to the plotted routes of the orbits it is apparent that through the zone of radio visibility of Noril'sk, and consequently, any other points on the

latitudes above 70°, communication (observation) is possible during the day at

all twelve orbits, i.e., practically every two hours, and in the middle latitudes,

on the order 55°, for example in Moscow, only on ten. On the southern border of

the territory of the USSR the number of orbits accessible for communication is

reduced to six. With passage of the trajectory of the AES flight near the zenith

of the reception-transmitting point the duration of the communications session can

reach 25 minutes. On the orbits that pass to the side of the zenith of the communi-
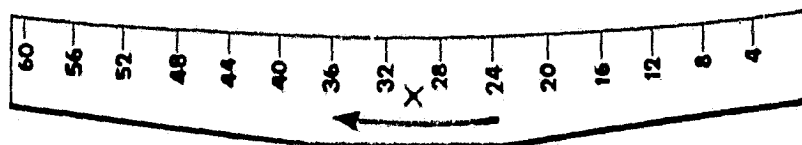
nications point it is noticeably reduced.

Figure 2.

TABLE 2.

No., Month	Name AES	No. in Order of Orbit	Time		Azimuth		Duration of Communications Session
			Ent. of AES into Zone	Exit of AES from Zone	Ent. of AES into Zone	Exit of AES from Zone	
1	2	3	4	5	6	7	8

For daily work the reference route is plotted on a transparent film (plexi-

glass) and fastened at the point of the geographical pole such that it can be

rotated around this point. One can also prepare a special template (figure 2)

which also is secured at the point of the North Pole and then is rotated.

During rotation of the film or template the beginning of the reference route

is coincident with the assigned values of longitude of the ascending junction. Then

the necessary time and duration of the communications session are defined, which

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New York

Vladivostok

Noril'sk

Moscow

center of
"communications circle"
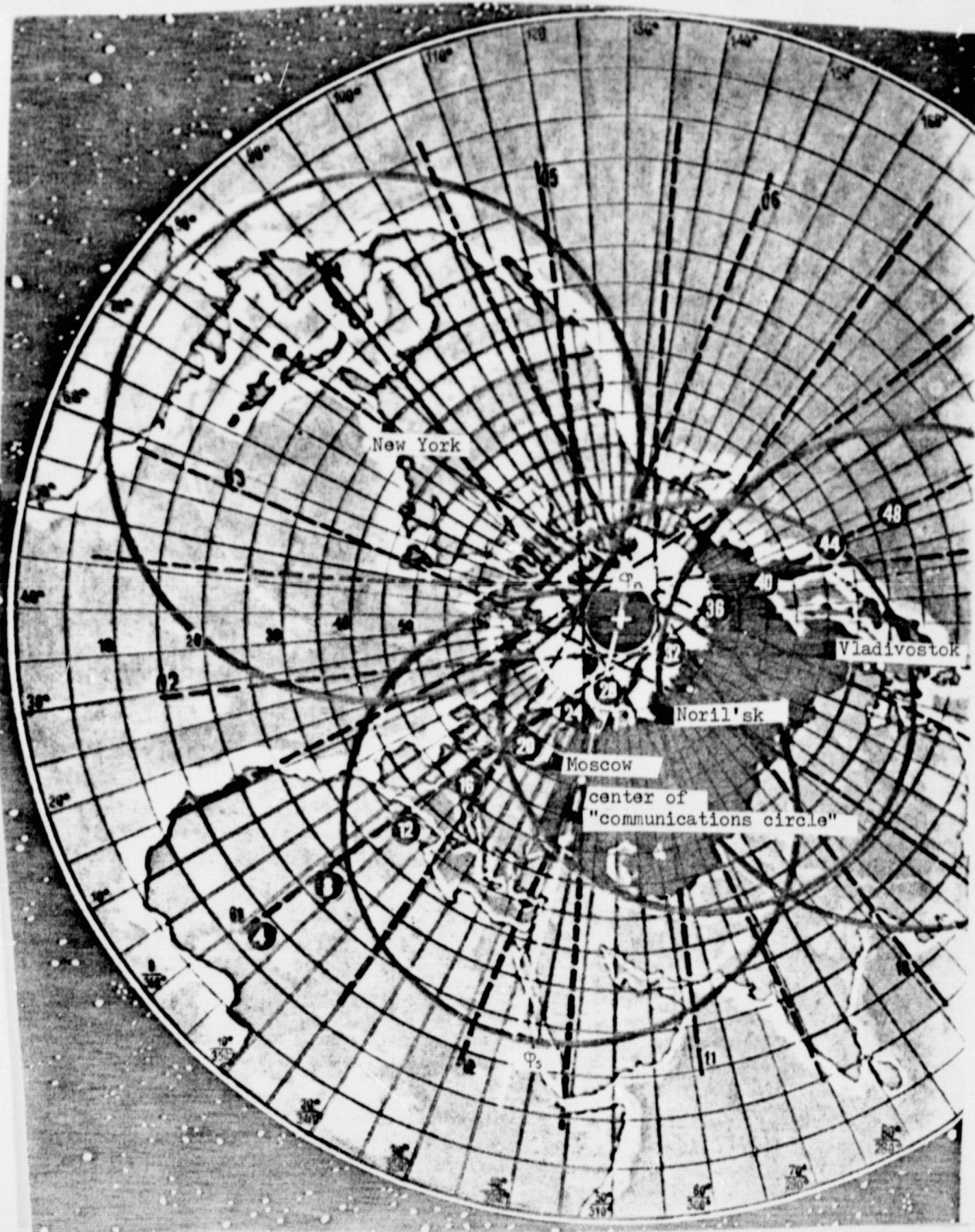
orbits and how many during the day are working, i.e., pass through the zone of radio visibility; the approximate direction (azimuth) of the appearance of the AES in the zone of radio visibility and the emergence from the zone, as well as on which orbits and under which conditions one can establish communication with the assigned point or region.

Recording of the predictable data of possible communications sessions (observations) through the retransmitting AES are conveniently presented in the form of table 2.

It is evident that the retransmitter simultaneously covers with the radio visibility the entire area of the earth's surface in limits of radius D/2 from the subsatellite point. Consequently, radio communication or observations are possible between all radio stations located within the limits of this area. Therefore if from the center of the zone of radio visibility a circumference is made of double radius, then it will determine the limit distance of communications from the given point. Similar communications are possible with the "touching" of the AES route of the boundary of the radio visibility zone at the point of intersection of it with the azimuth line on the correspondent.

The retransmitting satellites of the International Radio Amateur Organization AMSAT have orbits close to the circular and circumpolar.

Determination of the zone of radio visibility in calculation of the route can be made according to the stated technique.

References

1. Dobrozhanskiy, V. "Retransmitter: What it Should be Like," Radio, No 5 (1976), p 24, and No 9 (1976), p 13.

2. Dobrozhanskiy, V. "Retransmitter: How to Work Through It?" Radio, No 7 (1977), p 17, and No 9 (1977), p 23.

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FEATURES FOR CONDUCTING QSO

By V. Rybkin [UAZDV], USSR Master of Sports

Before the beginning of the practical work through amateur radio satellites it is necessary to prepare a plotting board with a tracking diagram (see the preceding article), to compile a schedule for passage of the space retransmitter, and to make a comprehensive evaluation of the reception conditions.

The schedule can be compiled approximately listening to the signals of the radio range beacon established onboard the satellite. For this, after tuning the receiver to the radio range beacon frequency, the length of its operation and silence are recorded. By using these data the time of radio visibility of the space vehicle is determined.

By receiving signals of the radio range beacon of different orbits from the entrance to the exit of the satellite from the zone of radio visibility one can precisely determine with which antennas and at what positions of the satellite on the orbit most favorable conditions are created for radio communication. The most objective evaluation of reception conditions is the level with which the signals of the beacon and the radio stations are received that are working through the retrans-

mitter. If this level is sufficient for positive conducting of radio communication--one can boldly broadcast. Otherwise it makes no sense to engage the transmitter--this will occupy the communications channel and will induce an irrational use of the power supply of the satellite from the signals of your station and the correspondents calling you.

The most characteristic feature of communication through a space retransmitter is the smooth change in the reception frequency governed by the Doppler effect [1]. The frequency of the radio range beacon during the session can reach 3 kHz (depending on the orbit), and the natural signal--up to 6 kHz. Thus it is necessary to continually readjust the reception frequency.

During communication extensive fadings of the signals are possible lasting up to tens of seconds, linked to the polarization changes on the route. As a rule, fading is one-sided, i.e., the signals of the correspondent can drop off, although at the same time he will have sufficiently positive reception.

For successful conducting of radio communication of the AES it is desirable to have both in the receiver and in the transmitter a precisely graduated scale. This will permit a significant reduction in the time for searching for the natural signal that has passed through the retransmitter. It is not complicated to make such scales, since the retransmitting band of frequencies usually comprises only tens of kilohertz (for example, for the satellites "Radio-1" and "Radio-2"--40 kHz).

As an exciter of the transmitter it is best of all to use the VXO--retunable quartz generator (for example, [2]). The possibility of regulating in broad limits the output power is mandatory for the transmitter.

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The transmitter should be tuned with an equivalent of the antenna. It is necessary to focus special attention on suppressing the stray channels with all possible correlations of the frequencies of the receiver and transmitter.

During work through a space retransmitter one can use either CW or SSB.

In a general call it is necessary to work on transmission with short "portions"--12...15 s with the same intervals. In the majority of cases you will begin to be called during your transmission, since communication during the satellite is completely two-way. After hearing the calls one should cease transmission: your correspondent will understand that you hear him and will transmit his call and RST or RS. In response the call of the correspondent, RST or RS and his call will be transmitted. It is necessary to maintain the loudness of your signal on a level S 5-S6 by the power regulation lever. Otherwise one can impair the conditions of radio exchange between other stations, reception of signals of the beacon and induce a useless (and sometimes dangerous for the satellite retransmitter) expenditure of energy onboard the AES. For positive communication effective (with regard for the coefficient of intensification of the transmitting antenna) emitted power for the satellites "radio" must not exceed 10 w.

In searching for your signal one should not transmit long series of points-- a situation is possible (see above) where the operator does not hear himself, but his signals (in the given case interferences!) impair other radio communication.

One should note that it is possible (with good calibration and graduation of the scales of the reception-transmitting apparatus, precise knowledge of the orbit, and consequently, superposition of the frequencies) to have communication also in the absence of your signal. In this case you will hear only your correspondent.

Such communication, in particular, is common in distant orbits.

If a response to the call did not follow, make a survey in the limits of the entire section. Stations can call you with rigidly fixed frequencies of transmission or with narrow-band retuning.

Communication through a retransmittor is distinguished by brevity, and its conducting to a great extent is similar to communication in large competitions. The two-way pattern promotes high efficiency and the best initial understanding to the correspondents. Usually radio exchange is limited to calls and evaluation of the received signal. Location of the stations and the name of the operator are reported usually in that case where the correspondent has asked for this.

With successful coincidence of circumstances radio communication can be conducted for 5 seconds.

To conduct long distance communication it is necessary for the AES to be located as close as possible to the horizon. Thus, the most valuable time for the DX QSO--is the beginning and end of the session. Radio communication is even possible when the satellite is located beyond the horizon. Therefore one should attentively begin to listen to the broadcast 1-2 minutes before the beginning of the session.

On the QSL besides the usual information it is necessary to indicate the name of the satellite through which communication was conducted, and the number of the orbit. It is also desirable to report how the communication was received in the VHF, square of the QTH-locator.

One should recall that amateur satellites are used as educational vehicles, and for conducting different experiments special days are set aside. It is cate-

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gorically forbidden to conduct radio amateur communication on this day.

In conclusion one can suggest that the local RTSh [working technical school] and the radio clubs organize issuing of a weekly bulletin that would report the number of the orbit, time and azimuth of appearance of the retransmitter in the zone of radio visibility for each of the radio amateur satellites that is active at the given moment.

References

1. Dobrozhanskiy, V. "Retransmitter: How to Work Through It?" Radio, No 9 (1977), p 23.

2. Kesker, E. "Simple VHF Transmitter," Radio, No 4 (1976), p 17.