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JPRS L/9073

7 May 1980

USSR Report

ELECTRONICS AND ELECTRICAL ENGINEERING

(FOUO 8/80)

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USSR REPORT

ELECTRONICS AND ELECTRICAL ENGINEERING

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UDC 548.0:537.001.1

DEVELOPMENT OF METHODS AND EQUIPMENT FOR PRODUCING LARGE CRYSTALS

Moscow ELEKTROTEKHNIKA in Russian No 11, 1979 pp 4-7 manuscript received 13 Mar 79

[Article by Candidate of Technical Sciences S. V. Bodyachevskiy, Engineer L. A. Avvakumova and Candidate of Technical Sciences E. Ye. Khazanov]

[Text] In connection with the need for new highly sensitive devices of various purposes, it becomes necessary to improve traditional methods of growing single crystals and to develop new methods when producing perfect and large crystals of such compounds as leucosapphire, alkali halides and alkali earth metals.

Obviously this problem cannot be solved by merely scaling up the size of the technological growth zone since processes of growing large crystals have a number of peculiarities.

In the synthesis of large crystals the boundary conditions of crystallization acquire an important role as they determine the intensity of heat transfer processes, and also the configuration of the temperature field in the system comprising the melt and the crystal. The fact that the surface of the crystallization front is well developed becomes important.

The techniques that show the greatest promise and have so far yielded the best results with respect to the mass and dimensions of the crystals produced are methods of growing from the melt such as the Stokbarger method, the Stober technique, the Kyropoulos procedure, the NYeM [expansion not given] method and the method of the moving isotherm.

The Stokbarger method is most extensively used in industrial and laboratory practice for producing such single crystals as sodium iodide, cesium iodide and fluorides of alkali earth metals (CaF_2, BaF_2).

The method consists in slow (1-5 mm/hr) vertical movement of a container with melt relative to a gradient temperature field.

The material crystallizes during this movement. After completion of growth, an isothermal field is set up in the volume of the crystal, and annealing is done by programmed change of temperature.

The major conditions for growing high-quality optical crystals can be formulated from an analysis of the data in the literature:

1. High axial temperature gradient (more than 10°C/cm) close to the crystallization front, held stable at the same level throughout the process. This condition is necessary to produce the maximum purification effect.

2. Flat or slightly convex form of crystallization front ensuring uniformity of the physical properties of the crystal over the cross section.

3. High time stability of temperature conditions (no worse than 1-1.5°C) and given rate of movement of the container to eliminate nonuniformity of movement of the crystallization front, and accordingly the nonuniformity of physical properties of the resultant crystal.

Crystal growing practice has shown that the first two conditions are easily realized in the traditionally used designs of facilities for producing crystals of fairly small diameter (up to 200 mm). An increase in the dimensions of crystals produced (primarily the diameter) disrupts the first condition of the growth process. An increase in diameter reduces the axial gradient. Besides this, considerable radial heat fluxes arise that distort the shape of the crystallization front as the charged container is moved.

In installations for producing large crystals of more than 300 mm diameter, heating elements are needed not only on the lateral surfaces of the container, but on the end surfaces as well to meet the conditions of growth considered above.

Taking all these considerations into account, the ISEV-8.8/15G facility was developed to provide conditions for producing fluorite crystals up to 600 mm in diameter. A diagram of the unit is shown in Fig. 1. It contains two end-face heaters 1 and 7, and two vertical heaters 2 and 6 separated by diaphragm 4. Each of the heaters has a self-contained power supply, regulation and programming of temperature conditions. The multiple-zone design of the heating chamber of this unit provides both a high axial temperature gradient close to the phase interface, and an isothermal surface with a nearly planar shape. Besides, the use of several heating zones makes it possible to combine gradient growth conditions with isothermal modes of crystal annealing in a single technological chamber. The design of the ISEV-8.815G facility is such that BaF_2 and CaF_2 crystals can be grown with good optical quality up to 600 mm in diameter and 100 mm high.

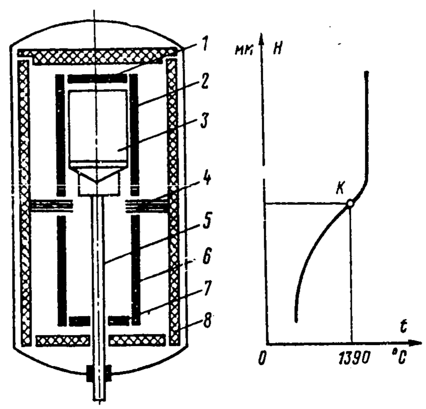

Fig. 1. Diagram of the heating chamber of the ISEV-8.8/15G facility, and nature of heightwise temperature distribution: 1, 2, 6, 7--heaters; 3--crucible with melt; 4--diaphragm; 5--rod; 8--heat insulation

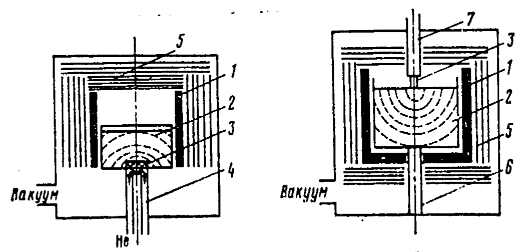

Fig. 2. Diagram of installations for growing leucosapphire crystals: a--by the heat-exchange method; b--by the Kyropoulos procedure; 1--heater; 2--crucible with melt; 3--seed crystal; 4--heat exchanger; 5--heat insulation; 6--crucible pedestal; 7--seed crystal rod; *Вакуум*--Vacuum

However, it should be pointed out that a complicated temperature-time program for each of the heating zones is needed to produce such large crystals on SEV type installations by the Stokbarger method. It is complicated to produce a precision mechanism for technological movement of a container with mass of several hundred kilograms. The large size of the unit (about 8 m high with area in the plan view of about 80 m^2) makes it difficult to service.

It can be assumed that fundamental and technical difficulties of producing still larger crystals (which are needed even now) will make it impossible to grow them by the Stokbarger method.

This problem can be solved when other methods are used such as the Stober technique in its various modifications. All installations that operate on this technique are typified by one particular feature: there is no mechanism for moving the crucible; the crystal is grown both by a programmed change in the temperature of the heating element, and by a simultaneous change in the temperature of the heater and directional heat transfer. This moves the crystallization front at a controlled rate either upward or downward (Fig. 2). The absence of moving parts in the facility considerably reduces overall dimensions, maximizes utilization of the working volume of the installation by the useful charge, and increases the yield of high-quality crystals by eliminating sources of vibration. Stober-process facilities have recently produced large leucosapphire crystals up to 225 mm in diameter and 125 mm high.

It should be noted that with the currently used precision programmed controllers, these facilities can produce high-quality crystals in a growth process with slow linear displacements of the crystallization front under conditions of low temperature gradients (0.5-1°C/cm). The successful application of the Stober principle in growing large leucosapphires has demonstrated its advantages for growing large crystals of calcium, barium and lithium fluorides.

The authors used the Stober principle to develop an experimental facility for growing lithium fluoride and calcium fluoride crystals 350-600 mm in diameter by the method of the moving isotherm. Use was made of experience in developing the ISEV-8.8/15G facility in producing crystals with height-to-diameter ratio of less than unity. A diagram of the heating chamber used for producing LiF crystals 350 mm in diameter is shown in

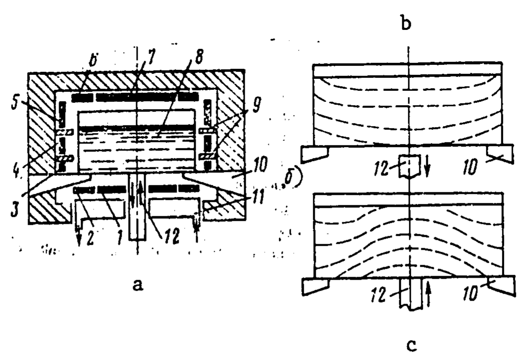

Fig. 3. Diagram of the heating chamber of a facility for producing crystals by the method of the moving isotherm (a), and the sequence of change in shape of the crystallization front depending on conditions of heat transfer with uniform heat transfer from the bottom of the crucible (b) and with nonuniform heat transfer (c): 1-7--heaters, 8--crucible with the melt; 9--diaphragms; 10--crucible supports; 11--cooler; 12--central rod of the cooler

Fig. 3a. On all inside surfaces of the chamber (the two end surfaces and the side surface) are heaters. Each of the end heaters is sectionalized into central and peripheral units to enable regulation of the heat flux with respect to the cross section of the crystal; the lateral heater is divided into three sections for controlling the shape of the horizontal isothermal surface by regulating the heat flux through the side sections of the refractory lining of the heating chamber. For purposes of localized action of the individually controllable zones of the corresponding sections of the crystal, these zones are separated by diaphragms. Directly beneath the heater in the lower part of the chamber is a cooler that is also sectionalized. The central part of the cooler is a rod 60 mm in diameter that can make direct contact with the bottom of the container.

This configuration enables regulation of the axial temperature gradient over a range of 0-12°C/cm. Each of the heaters has a self-contained power supply. The working temperature of each heater is regulated by a precision controller with accuracy of ±0.5°C. The sensor is a PR30/6 thermocouple. Programmed temperature variation in the working volume of the chamber is provided by a single BPV-8 controller with differential connection of the regulating thermocouples of all zones.

The seed crystal was placed in a graphite container. Since the process was carried out in air, the container was protected by a thin ceramic shell to prevent interaction between the graphite and atmospheric oxygen. After melting the initial charge and holding the melt under isothermal conditions at a temperature of about 950°C, a temperature gradient of about 10°C/cm is set up heightwise of the container by matching the working conditions of the end heaters and the cooler. Then the crystallization front is moved from the bottom upward by a simultaneous reduction of temperature on all heat zones. A rate of temperature change within the chamber of about 5°C/hr ensures a linear rate of crystal growth of about 5 mm/hr. After completion of the growth process, the crystal is annealed in the same chamber under isothermal conditions. The sequence of change in the isothermal surfaces on the various stages of growth is shown in Fig. 3b, c.

Uniform heat transfer from the bottom of the crucible produces a crystallization front of concavoplanar form. The planar front extends 300 mm when the crystal is 350 mm in diameter. Curvature of the front on the peripheral regions of the cross section is due to the structural peculiarities of the chamber, i. e. to the additional heat transfer from the crucible to the annular pedestal on which it rests. Nonuniform heat transfer from the bottom of the crucible due to direct contact between the central part of the cooler and the crucible produces a convexo-concave crystallization front.

No appreciable difference in the optical properties of the crystals produced was observed for these two shapes of isothermal surfaces. At the same time, the concavoplanar crystallization front leads to the formation of a large number of crystal blocks. Crystals produced by this method have high transparency in the ultraviolet region (from 0.2 to 0.3 μm) as compared with crystals grown in air by the Kyropoulos procedure.

The results of experimental studies have shown that the design of the unit provides the conditions needed for growing high-quality crystals.

The presence of sectionalized heaters on all surfaces of the chamber makes it possible to maintain isothermal conditions within the crystal to a high degree of uniformity [with variations of] less than 0.3°C/cm. At the same time, control of the temperature gradients and the shape of the crystallization front, especially conversion from the planar to the convex crystallization isotherm, is possible only to a certain degree. It was also shown that the degree of action of the lateral heating zones on the temperature field of the system comprising the melt and crystal is determined by the design of the container (its geometry, and the thermophysical properties of the material). This effect is minimum for the case of growing lithium fluoride crystals from a graphite crucible with ceramic shell. Therefore the number and dimensions of the lateral heating zones must be determined for each specific case.

The results of investigation of the conditions of growing lithium fluoride crystals 350 mm in diameter by the method of the moving isotherm served as the basis for development of the design of a facility for producing large fluorite crystals 600 mm in diameter. This process is carried out in vacuum at a temperature of about 1500°C. The diagram of the heating chamber of such a facility is shown in Fig. 4. In this

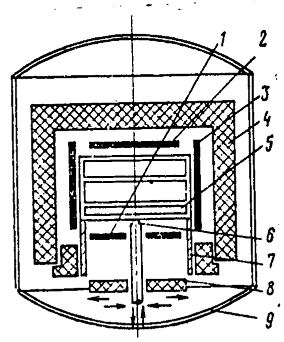

Fig. 4. Diagram of a facility for producing CaF_2 by the method of the moving isotherm: 1, 2, 3--heaters; 4--heat insulation; 5--crucible with the melt (three flat plates); 6--seed rod; 7--crucible pedestal; 8--extensible heat insulation; 9--cooler

design the heaters are also located on all inside surfaces of the chamber. The device for directional heat transfer in the lower part of the chamber is a combination of an end heater, extensible refractory lining and a cooler. This unit maximizes the axial gradient on the stage of growth during which the lower part of the refractory liner moves from the center of the furnace in the horizontal plane until the instant when the bottom of the crucible is completely aligned on the air-cooled housing. Crystal formation chiefly in the center of the crucible is attained by direct contact of the cooled rod with the bottom of the crucible. On the annealing stage, the refractory liner shields the crucible from the cooler, ensuring isothermal conditions in the crystal. The crucible is made up of two flat plates each 130 mm high, set one on top of the other, and a buffer plate 30 mm high for reducing uncontrollable temperature perturbations introduced primarily by the pedestal of the crucible. All elements of the heating chamber, including the crucible, are made of graphitized carbon materials.

Since experimental investigation of the temperature field during growth of fluorite crystals is not currently possible, a preliminary forecast was made of the temperature field in the working volume of the crucible filled with fluorite material, using programs on the Minsk-22 computer. In each of the variants of calculation, the various stages of the technological process of growing and annealing the crystals were simulated as a function of a given position of the crystallization front, the working conditions of the heaters and the relative location of the components of the directional heat transfer unit. The temperature field was calculated by a zonal method in which the cross section of the crucible with the crystal was broken down into a number of computational sections. The temperature was taken as constant within the limits of each section. The selected number of sections was 35. It was assumed that sections filled with crystal do not take part in radiant heat exchange, and thermal connection between adjacent sections of the crystal is only due to molecular heat conduction.

In this way, calculation of the temperature field was reduced to solution of a system of differential equations of first order in a number equal to the number of computational sections. The temperature field was determined in a two-dimensional system in which only the elements of the graphite crucible took part in radiant heat exchange, while the elements of the crucible and crystal took part in heat exchange by thermal conduction.

The results of the calculation show that the axial temperature gradient for the selected design of heating chamber is 5-9°C, while the radial temperature gradient is 0.3-0.6°C/cm.

Analysis of the results of calculation on the whole indicates that the proposed design is suitable for growing large fluorite crystals 600 mm in diameter and 100 mm high by the method of the moving isotherm.

Conclusions

1. The problem of developing technology and equipment for producing large bulk crystals in recent years has become one of the technological areas in the field of growing structurally perfect crystals.

2. The greatest success in dimensions of crystals produced has been achieved in facilities utilizing the Stober technique in various modifications, such as the NYeM method [expansion not given], a modified Kyropoulos procedure, and the method of the moving isotherm. Facilities of this type enable optimization of the thermal conditions of growing perfect large crystals, maximization of utilization of the working space of the heating chamber by the useful charge, appreciable reduction of the overall dimensions of the facility, and elimination of cumbersome mechanisms for crucible transport.
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Certain Aspects of Astronomy, Satellites and Space Vehicles

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SELECTING PARAMETERS FOR AN INTERSATELLITE COMMUNICATION LINK

Moscow ELEKTROSVYAZ' in Russian No 2 1980 pp 11-14

[Article by P. S. Kurakov: "Selection of Parameters of an Intersatellite Communications Link"]

[Text] Communications links between artificial earth satellites comprising elements of various satellite communication systems will make it possible to establish direct links between the ground stations of these systems without installing additional antennas and receiving-transmitting facilities at these stations.

Optimization of selection of the principal parameters of an intersatellite communications link: angles of separation between geostationary satellites, mode of aiming on-board antennas and their diameters, band of frequencies, etc -- will help increase the technical-economic effectiveness of intersatellite communications.

Angles of separation between geostationary satellites. It is expedient to employ intersatellite communication links on extended routes with the objective of encompassing the largest possible geographic area. Obviously the separation angles between satellites should be the maximum possible. We shall select angles of separation between satellites positioned in a geostationary orbit according to the criterion of amount of signal delay in a voice channel.

Usually signal delay on an earth-satellite-earth link is approximately 290 nsec. According to the recommendations of the International Telegraph and Telephone Consultative Committee [1], acceptable signal delays in a voice channel fall within the range of 150-400 nsec. Therefore the allowable signal delay time in a voice channel on a satellite-satellite link should not exceed 110 nsec. The angle of separation between satellites is detemined as follows:

$$\theta \leq 2 \arcsin \frac{tc}{2(R_з + H)}, \qquad (1)$$

where t is the allowable signal delay time in a voice channel between the two satellites; c -- velocity of propagation of radio waves; R_3 -- Earth's radius; H -- satellite altitude above Earth's surface.

Calculations indicate that the maximum allowable angle of separation between satellites should not exceed 50°. In our further discussion the term "small angles of separation" shall be applied to angles of separation between satellites in the order of 10°, and "large angles of separation" -- in the order of 50°.

Selection of method of aiming on-board antennas is determined by the cost of the communications system, power of the satellite-borne transmitters, and angle of separation between satellites. Employment of satellite-borne antennas without automatic tracking simplifies satellite design and reduces the cost of the communications system as a whole. It is expedient to employ such a mode of satellite-borne antenna aiming with small angles of separation between satellites. Systems with small angles of separation can be employed for communications between regional or international satellite systems without increasing the number of ground stations in each system. This is especially important for regional communications systems, which may include small countries with light traffic but which require communications with countries employing other satellite communications systems.

It is advisable to employ satellite-borne antennas with automatic tracking mode in communications systems with large angles of separation between satellites. Such systems can cover substantial geographic areas. Their employment makes it possible: to expand the service zones of the network of ground stations, to establish a flexible and extensive satellite communications network, to employ (to the extent that this is technically possible) higher frequency bands, to reduce the required power of satellite-borne transmitters and, correspondingly, power consumption from primary power supplies.

Optimal diameters of satellite-borne antennas. An analysis of the graphs contained in [2] indicates that on the basis of power considerations, it is desirable to select as large a diameter as possible for satellite-borne antennas. With an increase in antenna diameter, taking account of instability of antenna aiming (automatic tracking mode not employed), the minimum required power for satellite-borne transmitters shifts in the direction of the lower frequencies. With a high degree of instability, in the order of 1°, an increase in antenna diameter provides no gain in the system's power indices. In addition, maximum antenna size is limited by the size of the platform, demands on the system's mechanical and electrical parameters, as well as by satellite cost.

There evidently exists an optimal relationship between satellite cost, diameter of satellite-borne antenna and power of satellite-borne transmitter. In [3], satellite cost is determined as follows, in relation to satellite-borne transmitter power $P_б$, number of satellite-borne repeaters n_p and service life t:

$$C_{\text{ИСЗ}} = a_1 P_{\text{б}}^{x_0 + x_1 t}\, n_{\text{p}}^{x_2 + x_3 t}, \qquad (2)$$

where a_1 and x_1 are constants.

Formula (2), however, does not take account of the relationships between satellite cost and and antenna diameter D_a with an intersatellite tracking system, and operating frequency of output devices. Taking these parameters into account, satellite cost can be represented as follows:

$$C_{\text{ИСЗ}} = a_1 K(f)\, P_{\text{б}}^{x_0 + x_1 t}\, n_{\text{p}}^{x_2 + x_3 t} + a_2 D_a^{x_4 + x_5 t} + a_3, \qquad (3)$$

where K is a coefficient determined by frequency f. The relationship between satellite cost and transmitter power is expressed by the power 0.65, and with antenna diameter -- by the power 2.0 [4]. The ratio of the cost of all repeaters to the cost of the antenna system in satellite communication systems which have been developed and are in operation is 2.5-3.0.

Coefficient $K(f) = \sqrt[m]{f/4}$, where m ranges between 3.5 and 4.0. Satellite-borne transmitter power can be represented by the following expression [2]:

$$P_{\text{б}} = \frac{64 \cdot \pi^2 \sin^2 \frac{\theta}{2} (R_3 + H)^2 L_{\text{доп}}}{\lambda^2 G_{\text{пер}} G_{\text{пр}} \eta_{\text{пер}} \eta_{\text{пр}}} \times P_{\text{ш}} \left(\frac{P_{\text{c}}}{P_{\text{ш}}}\right)_{\text{вх}}, \qquad (4)$$

where θ -- angle of separation between satellites; $P_{\text{ш}}$ -- noise strength at receiver input; $\left(\frac{P_{\text{c}}}{P_{\text{ш}}}\right)_{\text{вх}}$ -- signal-noise ratio at receiver input; λ -- wavelength; $G_{\text{пер}}, G_{\text{пр}} = q \frac{\pi^2 D_a^2}{\lambda^2}$ -- transmitter and receiving antennas respectively; q -- coefficient of reflector surface utilization; $\eta_{\text{пер}}$; $\eta_{\text{пр}}$ -- coefficients of power transmission by the transmitting and receiving antenna-waveguide circuit; $L_{\text{доп}}$ -- additional signal losses in the atmosphere.

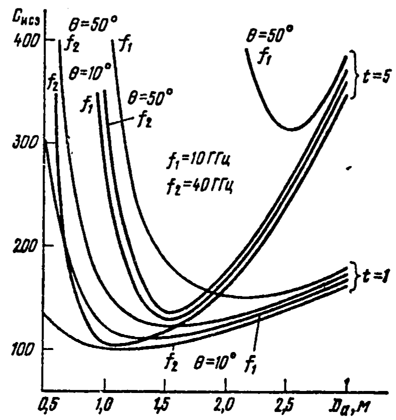
Expression (2) can be represented in the following form:

$$C_{\text{ИСЗ}} = a_1 \left(\frac{a_4}{D_a^4}\right)^{x_0 + x_1 t} n_{\text{p}}^{x_2 + x_3 t} + a_2 D_a^{x_4 + x_5 t} + a_3, \qquad (5)$$

where

$$a_4 = \frac{64 \cdot \lambda^2 \sin^2 \frac{\theta}{2} (R_3 + H)^2 L_{\text{доп}}}{q^2 \pi^2 \eta_{\text{пер}} \eta_{\text{пр}}} \times P_{\text{ш}} \left(\frac{P_{\text{c}}}{P_{\text{ш}}}\right)_{\text{вх}}.$$

The results of calculations with formula (5) are plotted in the figure for cases of small and large angles of separation between satellites during satellite operation in orbit; t -- one and five years duration. It is evident from the graph that the relative cost of a satellite depends on antenna diameter, angles of separation between satellites, as well as the band of operating frequencies of the satellite-satellite communication link. For small angles of separation between satellites the optimal size of satellite-borne antennas, depending on frequency, ranges from 1 to 1.5 m, while for large angles of separation the relative cost minimum displaces to the right, in the direction of larger antenna sizes, and the optimal antenna size falls within the range 1.5-2.5 m.



Optimal frequency bands and required transmitter powers. Operating frequency band is an important parameter of a satellite-satellite communication link. (In 1971 the World Administrative Radio Conference on Space Communications assigned a band of frequencies above 50 GHz for intersatellite communications). Selection of an optimal communication link frequency band is influenced by the operating mode of the satellite-borne antenna systems. We shall adopt the minimum requisite satellite-borne transmitter power as criterion of optimal selection of frequency band.

The relationship between the requisite satellite-borne transmitter power on the one hand and band of operating frequencies, angles of separation between satellites, diameter of antennas and antenna aiming error in automatic tracking mode on the other is determined by the following expression [2]:

$$P_{\text{пер}} = 16{,}38\cdot 10^{22}\,\frac{\sqrt{f/6}\,\sin^2\frac{\theta}{2}}{f^2 D_a^4} + 10^{\frac{-\frac{1}{2}\sigma^2 f^2 D_a^2}{4{,}58\cdot 10^{4}}}, \qquad (6)$$

where σ -- satellite-borne antenna aiming error in degrees. From formula (6) one can readily find the optimal operating frequency value, which is determined by aiming error and antenna diameter, at which the required transmitter power is minimum. We shall find that

$$f_{опт} = \frac{14}{\sigma D_a}, \text{ ГГц.} \quad (7)$$

On the basis of selected diameters of satellite-borne antennas at σ =0.5°, optimal communication link operating frequencies fall within 18-28 and 11-18 GHz for small and large angles of separation between satellites respectively. With a decrease in antenna aiming error to σ =0.3°, the optimal range of satellite-satellite communication link frequencies with small angles of separation falls within limits 30-46 GHz.

Employment of frequency bands above optimal for each specific antenna diameter in communication links without automatic tracking is not advisable due to a sharp increase in the required power of satellite-borne transmitters. At large angles of separation between satellites without automatic tracking mode, rather high transmitter powers are required, and correspondingly high-output primary power supplies. Therefore employment of such an antenna operation mode is not advisable with large angles of separation between satellites.

When satellite-born antennas operate on automatic tracking mode, required satellite-born transmitter power decreases with an increase in operating frequency and antenna diameter, and therefore in this instance it is preferable to utilize higher frequency bands. Analysis of the accompanying graph indicates that with small angles of separation between geostationary satellites, satellite cost is negligibly dependent on frequency. Taking this into account, with small angles of separation between satellites and antennas not operating in automatic tracking mode, it is advisable to employ frequency bands (22-23.5 GHz) permitting simplification of satellite design. Utilization of low frequency bands is economically inadvisable with large angles of separation between satellites.

It is apparent from the figure that relative satellite cost increases approximately threefold in comparison with the cost of a satellite employing higher frequency bands (40 GHz). Therefore with large angles of separation between satellites it is advisable to employ higher frequency bands. The service life of high-powered satellite-borne equipment, however, decreases thereby. Taking account of the available technological base, economic considerations, possibilities of combining operations without mutual interference with other communications services, as well as trends in and the state of development of space technology, it would seem advisable to utilize for a satellite-satellite communication link with large angles of separation the 31-33 and 37-40 GHz bands.

Electromagnetic compatibility with terrestrial services. The frequency bands designated above as optimal for a satellite-satellite communication link with small angles of separation between satellites are quite extensively employed in ground communication links and have not been assigned to intersatellite communication service by Radio Communications Regulations.

Let us analyze levels of interference to terrestrial radio communications services from a satellite-satellite communication link employing the frequency 22 GHz. For a communication link with small angles of separation between satellites and with satellite-borne antennas not employing automatic tracking, effective isotropic-radiated signal power with the above-specified system parameters (transmitter power 12 dbw, antenna diameter 1.5 m, frequency 22 GHz) will be as follows:

$$EIRP=P_{\pi ep}G=60.2 \text{ dbw},$$

where $G=\frac{q\pi^2 D_a^2}{\lambda^2}=48{,}2$

db -- antenna gain at 15 GHz; q=0.55 double-antenna reflector surface utilization factor. Assuming that the ratio of unmodulated carrier power to power spectral density in any band 4 kHz in width of a modulated carrier is equal to 30 db [5], we obtain EIRP=33.2 dbw.

Assuming Earth-facing antenna gain at 0 db, since the angle between a line bearing on the other satellite and a line pointing to the Earth is approximately 80°, we obtain in the direction of the Earth, in any band 4 kHz wide, ERIP=-15dbw.

Let us determine power flux density at the Earth's surface: F=EIRP-10 log $(4\pi D^2)$=178.5 dbw/m^2 in any band 4 kHz wide, D=42 x 10^6 m -- distance to the Earth's surface for small wave angles of arrival to the horizon. With an International Radio Consultative Committee standard of -115 dbw/m^2 in any band 1 MHz wide, we obtain a power flux density at the Earth's surface of 39.5 dbw/m^2 below standard. Even with large angles of separation between satellites (θ=50°, required satellite-borne transmitter power $P_{\pi ep}$=20 dbw), power flux density at the Earth's surface is approximately 23 db below the IRCC standard.

In like manner one can determine the power flux density at the Earth's surface in the 37-40 GHz band when EIRP=5 dbw, D_A=2 m, and f=38 GHz. It is within the limits of -161.5 dbw/m^2 in any band 1 MHz in width. No IRCC standards exist for this band. Restriction on power flux density produced at the Earth's surface by space station emissions terminates with the 22 GHz band, for which it should not exceed -115 dbw/m^2 in any 1 MHz bandwidth with small radio wave arrival angles. Adopting this figure for the 31-40 GHz band, we conclude that in this band terrestrial services will not be affected by interference from a satellite-satellite communication link. The above calculations do not take account of signal attenuation resulting from absorption of radio waves in the atmosphere, which additionally increases the protection ratio.

We shall evaluate the level of intersatellite link interference from ground communication links employing the same frequency band. The provisions of the Radio Communications Regulations prohibit ground services from radiating signals in the direction of a geostationary orbit in a band of frequencies 10-15 GHz, the EIRP of which exceeds 45 dbw. The axis of the principal lobe of an antenna's radiation pattern should be directed 1.5° away from a geostationary orbit. Maximum EIRP of terrestrial services stations should not exceed 55 dbw in any event. No restrictions are imposed on frequency bands above 15 GHz in respect to direction of maximum radiation toward a geostationary orbit.

Let us determine interference power at satellite-satellite communication link receiver input from terrestrial communications equipment operating in the 22 and 38 GHz band, in the assumption that the ground station antenna is aimed directly at the geostationary orbit. Then: $P_{\pi} = EIRP_H + G_{\pi p} - L_{\Sigma}$, where P_{π} -- interference power at receiver input; $EIRP_H$ -- effective isotropic-radiated power of ground communications facilities; $G_{\pi p}$ -- satellite-satellite communication link receiving antenna gain in the direction of the Earth; $L_{\Sigma} = 20 \log(4\pi D/\lambda)$ -- attenuation of energy in free space, when D=42,000 km we obtain: P_{π}=-157 dbw for f=22 GHz, and P_{π} = -165.5 dbw for f=38 GHz.

Useful signal power at satellite-satellite communication link receiver input with small angles of separation between satellites and selected communication link parameters is P_c=-88.2 dbw when D=7,362 km. For large angles of separation P_c=-100.7 dbw, and then the signal-noise ratio at receiver input will be $\frac{P_c}{P_{\pi}}$ = 68.8 db for f=22 GHz, θ=10°; $\frac{P_c}{P_{\pi}}$ =60.8 db for f=38 GHz, θ=50°.

Conclusion. Results of calculations indicate that satellite-satellite communication links operating in the above-specified optimal frequency band of 22-23.5, 25.5-27.5, 31-33, and 37-40 GHz are entirely compatible with terrestrial communications systems with frequency assignments in these bands in conformity with the Radio Communications Regulations [6].

Bibliography

1. MKKTT [International Telegraph and Telephone Consultative Committee], Vol 3, Part 1.

2. Kurakov, P. S. "Theoretical Analysis of Energy Correlations With Signal Relaying Between Satellites," VOPROSY RADIOELEKTRONIKI, Radio Communications Technology Series, No 2, 1978.

3. Talyzin, N. V., et al. "On Optimal Parameters and Economic Effectiveness of a Multistation Satellite Communications System," RADIOTEKHNIKA, Vol 24, No 11, 1969.

4. Kane, D. A., and Jeruchim, M. C. "Orbit/Spectrum Utilization Study," Vol III, General Electric, Space System Organization, 1970.

5. "Documents CCIR Study Groups (1974-1978)," Document 9/13.

6. "Reglament radiosvyazi" [Radio Communications Regulations], Moscow, Svyaz', 1975.

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"MOSKVA" SATELLITE TV TRANSMISSION SYSTEM

Moscow ELEKTROSVYAZ' in Russian No 1, 1980 pp 6-10

[Article by L. Ya. Kantor, V. P. Minashin, I. S. Povolotskiy, A. V. Sokolov and N. V. Talyzin, submitted 5 Sep 79]

[Text] The goal of further development of TV and radio broadcasting formulated by the 25th CPSU Congress is being successfully resolved by the wide utilization of artificial earth satellites. Operating satellite TV transmission systems in the country, the "Orbita" and "Ekran" [1], have been supplemented by new, efficient distribution system, "Moskva", which operates via the "Gorizont" communications satellite. The "Moskva" system was designed for professional reception of satellite TV transmission signals and for relaying of received programs to ground-based TV broadcasting centers (air or cable).

Basic Principles

The fascinating possibility of total coverage of the country with TV transmissions arose with the establishment of a TV distribution system in the 4 GHz range. This system supplements the existing distribution system in the 4 GHz which is set aside for fixed services as well as other systems. To create an efficient distribution system for satellite TV transmission in this frequency range, special barrels on geostationary multibarreled satellites should be employed. These barrels should have increased output capacity and a narrow beam antenna. Transmitter output and antenna gain on an on-board retransmitter should be selected to not exceed the maximum permissible output flux density of power in the 4 kHz band at the Earth's surface, which is equal to 152 dBW/m^2 x 4 kHz for the 4 GHz range [2]. This constraint on output flux density has been established by Radio Communication Regulations in view of the combined use of the 3400-7400 MHz frequency range by orbital and ground-based services, especially radio relay lines [3]. Service zones for TV distribution systems must be selected on the basis of the accepted principle of broadcasting in the USSR where no more than 2-3 time zones are contained within a single zone.

The use of these principles to set up a distribution system, which received the provisional name "Moskva", greatly simplified and reduced the costs of the ground-based receiving stations in comparison with the "Orbita" station by reducing antenna dimensions, obviating the need for a complex tracking system, and by using a relatively simple input device. The "Moskva" system will be able to serve any region in the land, especially the European part and the Far East, since there is no danger of interference with ground-based services.

Basic Technical Specifications and Qualitative Indicators of the "Moskva" System

This system is constructed on the basis of utilization of the power barrel of the "Gorizont" artificial Earth's satellite [4].

Parameters of "Gorizont" satellite power barrel [5]

Total peak output of on-board transmitter fed to satellite antenna, Watts	40
Satellite transmitting antenna gain, dB	30
Frequency band, MHz	36
Permissible positional deviation of satellite from nominal, degrees:	
in longitude	± 0.5
in latitude	± 1.2

Quality Indicators of Image Channel

Uppermost TV channel frequency, MHz	6
Weighted signal-to-noise ratio in image channel output, dB	53
Signal-to-background ratio at image channel output, dB	35
Nonlinear distortion in brightnesss signal, maximum, percentage	15
Types of distortion:	
"gain differential", percentage	10
"phase differential", percentage	8
Distortion of transient characteristic in region of:	
average time, maximum percent	5
long term, maximum, percent	10
short term	patterned after GOST 19463-74
Nonuniformity of amplitude-phase characteristic of video channel	patterned after GOST 19463-74

Quality Indicators of Sound Sync and Radiobroadcast Channels

Uppermost frequency in sound signal spectrum, kHz	10
Weighted signal-to-noise ratio in channel, dB	57
Suppression of audible transient noise, minimum, dB	70
Coefficient of harmonics at 800 Hz, percent	2
Nonuniformity of amplitude-phase characteristic at frequencies, Hz, percent:	
50-100 and 8,000-10,000, dB	+1.8 / -4.5
100-200 and 6,000-8,000, dB	+1.8 / -2.6
200-6,000, dB	±1.8

The central TV channel from the All-Union Radio and Television Transmitting Station, ORPS, is fed through ground-based connecting links to a ground-based transmission station which has receiving and transmitting equipment for all artificial Earth's satellite barrels of "Gorizont", including the "Moskva" system. The FM signal shaped at the station is fed through a 12 meter antenna common to all barrels and is emitted toward the artificial Earth's satellite. This signal is received by the artificial Earth satellite, is amplified, is modulated and is emitted toward the appropriate service area within the Soviet Union.

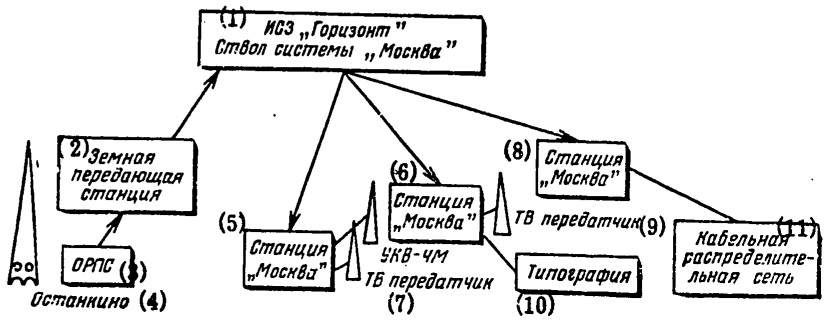

Figure 1

Key:

1. "Gorizont" satellite, barrel of "Moskva" system
2. Ground-based transmitter
3. ORPS
4. Ostankino
5. "Moskva" station
6. "Moskva" station
7. USW-FRM TV transmitter
8. "Moscow" station
9. TV transmitter
10. printing house
11. Cable distribution network

The transmitter of the ground-based station is similar to the transmitters of the "Ekran" system [9] or "Intersputnik" [7], but a special TV signal and dispersion insertion units are connected in front of the frequency modulator, as is the sound sync and radio transmitting equipment.

The satellite-retransmitted signal is received by a network of ground-based receiving stations and then enters a TV transmitter of 1, 10 or 100 W output, which is used to feed the received program to subscribers. The receiving station also has the ability to feed the cable distribution network. Radio broadcast signals are fed to a local radio translation network or to an ultrashort wave FM radio transmitter.

These qualitative indicators are open characteristics and relate to the entire system as a whole.

With the above parameters of an on-board retransmitter, the integral flux density of output at the Earth's surface is about 120 dBW/m^2. Because of the insertion of a dispersion signal, the outupt flux density recommended above is always asssured in the 4 kHz band. At this density the receiving station can employ a small antenna.

Table

Parameter	Notation	Value	Unit of Measurement
Equivalent isotropically emitted output of on-board transmitter	$EIIM_b$	43	dBW
Total losses in signal propagation in satellite/Earth line	L	198	dB
Receiving antenna gain	G	37.5	dB
Equivalent noise temperature of receiving station	T_N	200	K
Noise band of receiving station	Δf_N	37	MHz
Boltzmann's constant	k	-228.6	dBW/HzK
Signal/noise ratio at receiver input	$(P_s/P_n)_{in}$	12.5	dB
Maximum frequency of videosignal	F_v	6	MHz
Deviation in frequency allocated to image signal (without sync pulses)	Δf_d	9.1	MHz
FM gain in image channel	G_{FM}	13.5	dB
Weighted signal/noise ratio at output of image channel	$(P_s/P_n)_{im}$	53	dB
Deviation in frequency allocated to audio subcarrier	Δf_{ds}	1	MHz
Subcarrier frequency	f_s	7(7.5)	MHz
Subcarrier frequency deviation	W	150	kHz
Maximum frequency in audio spectrum	f_m	10	kHz
FM gain in audio channel	G_{FMaud}	38	dB
Signal/noise ratio in audio sync channel (radio broadcast)	$(P_s/P_n)_{aud}$	57	dB

Antenna dimensions were selected on the basis of several contradictory factors. On one hand, an enlargement of the antenna assures greater gain and the desired signal level at the receiver input. On the other hand, to simplify the receiving station, it is desirable to avoid a complex tracking system and thus the antenna beam pattern should be rather wide, according to possible orbital wobble of the satellite.

Consideration of the above factors as well as the attempt to maximally simplify and lower the price of the station defined an antenna diameter of 2.5 meters and beam pattern width of $\pm 1^{\circ}$, with no automatic satellite tracking system. In some instances, when unattended stations are designed, the station's reception quality is affected for a long while by the operational instability of the ground-based receiving antenna's orientation and may require the use of a simple automatic following system, which will be discussed in greater detail below.

The "Moskva" uses a non-cooled parametric amplifier with noise temperature less than 100 K as an input device. This temperature is similar to the maximally permissible level for simple non-cooled amplifiers with few stages under the aforementioned operating conditions.

Energy indicators of the communications line in the "Moskva" system enable FM arrangement of one image channel and two audio sync channels. To achieve required TV signal quality, deviation of frequency for the video signal should be $\pm$ 13 MHz. For audio sync and radio broadcast channels, carrier deviation must be $\pm$ 1 MHz. Therefore, the total peak frequency deviation in the "Moskva" system is $\pm$ 15 MHz, which coincides with frequency deviation in the "Orbita-2" and "Intersputnik" systems [6, 7].

Audio sync and radio broadcast signals are transmitted by FM at subcarrier frequencies of 7 and 7.5 MHz. Frequency deviation of subcarriers is $\pm$ 150 kHz. To improve audio sync channel quality, a variable compression expander is utilized.

The method of audio signal transmission in the "Moskva" system differs from methods used in the "Orbita-2" and "Ekran" systems. The use of a time method of audio signal transmission in the "Orbita-2" system enables arrangement of two audio sync channels only when very complex, expensive equipment is used [6].

The use of the frequency method in the "Ekran" system, i.e., transmission of audio signals on a subcarrier of 6.5 MHz with frequency deviation of 50 KHz simply assures a standard signal of the ground-based TV broadcast [1], but it is poorly suited for the "Moskva" system. Simple total TV signal shapers without audio subcarrier demodulation used in the "Ekran" system do not permit companders to be used to reduce noise level. Furthermore, to obtain the necessary signal quality in the audio sync channel when a smaller frequency deviation is utilized, energy losses must be permitted in the image channel. The frequency of the subcarrier 6.5 MHz is situated too near the limiting frequency of the video signal, causing some problems in designing a filter to separate the audio sync and video channels; in addition, it is hard to maintain the low level of transient noise from the image channel into the audio sync channel required for mainline feed of TV programs.

Energy relations for the "Moskva" system were calculated using formulas of study [8].

The signal/noise ratio at the station's receiver input

$$\left(\frac{P_c}{P_N}\right)_{in} = EIIM_b - L + G - K - T_N - \Delta f_N, \quad dB;$$

the signal/weighted noise gain at the output of the image channel

$$\left(\frac{P_c}{P_N}\right)_{im} = \left(\frac{P_c}{P_N}\right)_{in} + V_{FM} + 26.8, \quad dB;$$

gain from the use of FM in the video channel

$$V_{FM} = 10 \log \frac{3}{2} \frac{\Delta f_N \Delta f^2_d}{F^3_v}, dB;$$

the signal/psophometric noise ratio at the audio sync channel output

$$\left(\frac{P_c}{P_N}\right)_{aud} = \left(\frac{P_c}{P_N}\right)_{in} + V_{FMaud} = 10, \quad dB;$$

gain from using FM in the audio sync channel

$$V_{FMaud} = 10 \log \frac{3}{2} \frac{\Delta f_N \Delta f^2_{ds} W^2}{f^2_p f^3_v}.$$

The notations used in the formulas and the results of calculation are cited in the table.

The functional circuit of the "Moskva" sytem is shown in Figure 1. The system contains: a ground-based transmitting station; aerospace segment—one "Gorizont" satellite barrel (registration index "Statsionar"); network of ground--based receiving stations.

To cover the territory of the Sovet Union with television broadcasting may require several aerospace segments arranged, for example, at the points announced for the "Statsionar" satellite 53, 90, 140° Eastern Longitude.

It is possible to establish transmission of an image of newspaper columns instead of a radio broadcasting channel; this is doubtless the merit of the "Moskva" system, since the installation of a station in the direct proximity of the printing house obviates the need for building connecting lines.

At the transmitting station, the signal is specially processed. It consists of limiting surges which occur at fronts of video signal pulses subject to standard linear predistortion. By increasing frequency deviation of the TV signal, it is possible to improve image quality by 2-3 decibels [8, 10].

A distinctive feature of the receiving station is the possible use of a simple tracking device. Use of this device is advisable in view of the aforementioned latitudinal instability of the satellite, and also because of the desire to eliminate possible signal losses due to inaccurate tracking of the satellite by the ground-based antenna which occurs during the operating process. Tracking is accomplished by rotating the beam pattern of the receiving antenna by displacing the feed from the reflector focal point. The angle of rotation of the beam pattern is roughly equal to the angle at which the feed rotates. Automatic tracking is done by an extreme automaton which automatically finds the three-dimensional maximum of the signal and then keeps the antenna feed within 0.25° of the necessary position [11].

Electromagnetic Compatibility

When the "Moskva" system was designed, a great deal of attention was given to questions of electromagnetic compatibility (EMC) with ground-based and satellite communications systems operating in the 4 GHz range. The chief problem was to meet IRCC standards for output spectral flux density at the Earth's surface generated by an aerospace transmitter. Flux density, as was said above, should not exceed -152 dBW/m^2 in any frequency band 4 kHz in width. When this condition is met, there is no danger that the system will generate interference with ground-based services, especially radio relay lines, even with extremely unfavorable (i.e. energy dissipation) image subjects. It appears that the minimum output flux density measured in any 4 kHz band is achieved with a uniform signal output distribution in the entire frequency band allocated for it.

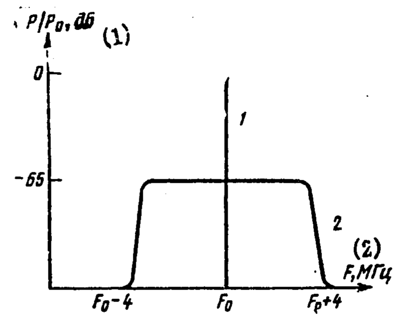

Figure 2

Key: (1) P/P_0, dB (2) F, MHz

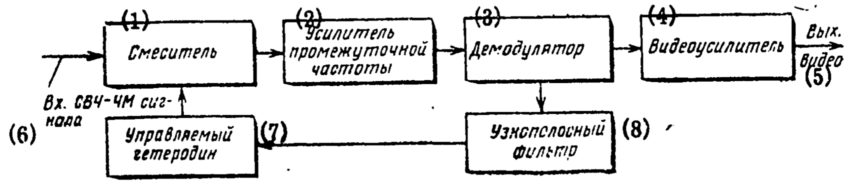

Figure 3

Key: (1) mixer
(2) IF amplifier
(3) demodulator
(4) video amplifier
(5) video output
(6) SHF input of FM signal
(7) variable heterodyne
(8) narrow band filter

We know that the TV spectrum of an FM signal is not uniform; consequently, flux density in the worst 4 kHz band may, in several instances, be only 2-3 dB lower than in the case of an unmodulated carrier. Based on the fact that output flux density of an unmodulated arrrier at the Earth's surface is -120 dBW/m^2 x 4 kHz, it is necessary to utilize artificial power dissipation with the aid of a dispersion signal.

In the "Moskva" system, a triangular dispersion signal is used because the FM spectrum of such a signal is most uniform. The frequency of the dispersion signal was selected as 2.5 Hz. This selection is justified primarily because the disersion signal can be efficiently subtracted in the receiver by a narrow band frequency-feedback filter (OSCh). On the other hand, choice of this frequency apparently does not degrade dispersion efficiency. Indeed, in a radio relay telephone line, noise output is standardized as an average per minute; it may thus be considered that the average noise output per minute is independent of the dispersion signal frequency. However it should be noted that with such a low dispersion signal frequency, noise in the telephone channel becomes quite clear and the problem of the influence of this noise requires further study. Deviation allocated to the dispersion signal is selected on the basis of the required degree of carrier dissipation and comes to $\pm$ 4 MHz, with a small margin. Figure 2 shows the spectrum of an unmodulated carrier (curve 1) and a carrier modulated by a dispersion signal with 4 MHz deviation (curve 2).

In the receiver, the dispersion signal is subtracted using the OSCh device. The functional diagram of the device is shown in Figure 3. Choice of dispersion signal frequency below the video signal spectrum enables it to be filtered out and to close the OSCh circuit only on the disperison signal. The receiver's bandpass is calculated to pass the FM signal modulated only by useful message, because frequency deviation for the dispersion signal is greatly reduced. This solution makes it possible to avoid losses in noise immunity which would appear if the receiver's bandpass were enlarged.
The residual dispersion signal is removed by "clamping" the image signal level.

Let us briefly discuss the possible effect of radio relay lines on "Moskva" system stations. In the given case, EMS is guaranteed by selection of the central frequency of the "Moskva" system barrel in a "window" of the frequency plane of many domestic radio relay lines. The closest carrier frequency of the radio relay lines is 9 MHz away from the central frequency of the system's barrel.

Furthermore, an efficient choice of area for installation of the "Moskva" station makes it possible, in most cases, to avoid noise even from closely situated radio relay line stations. As experience has shown, when an area is selected for locating a "Moskva" system station, because of the small size of its antenna it is possible to use the screening of natural obstacles, various buildings and structures.

The amount of station equipment of the "Moskva" system is so small that it can be placed in existing buildings, for example, in a communications junction building, in a rural clubhouse or in a small TV retransmitter. The antenna can be set on the roof or on the group, on concrete or rock slabs, using simple metal brackets. Installation, assembly and setting into operation may be accomplished in a few days. The station requires no constant qualified technical servicing. The technical servicing system operates on a zonal principle: there is a so-called zonal service station for every 7-10 unmanned receiving stations, provided with the necessary measuring instruments, spare parts kits and transportation. The zonal station has servicing personnel with very high qualifications who carry out preventive maintenance and repair work at all zonal stations every 1, 3, and 6-12 months.

Conclusion

The "Moskva" system is successfully undergoing testing. Several receiving stations, including portable ones, have been set up in different points in the zone.

The results of testing have corroborated the validity of the basic technical decisions. The "Moskva" system creates no interference with ground-based services. Quality indicators of image and sound sync channels satisfy the norm and exceed the norm in several parameters, especially signal/noise ratio in the video channel, which is at least 54 dB. During the testing process it was found possible to receive images of newspaper columns at the "Moskva" system station. Testing results were successful.

References

1. Minashin, V.P., Fortushenko, A.D., Borodich, S.V., Kantor, L. Ya., Bykov, V.L. Basic principles of the "Ekran" system, Elektrosvyaz', No 5, 1977

2. USSR Patent. No. 302840. Method of radio communications and TV transmission using artificial Earth satellites. Inventors: Kantor, L. Ya. Talyzin, N.V. and Bykov, V.L.

3. Radio Communications Regulations.

4. TASS report, from Pravda dated 21 Dec 78, No. 355 (22055).

5. Special section of SPA AA/108/1210 to IFRB Circular No. 1210 dated 20 Apr 76.

6. Kantor, L. Ya., Polukhin, V. A., Talyzin, N. V. New orbital communications satellites, "Orbita-2", Elektrosvyaz', 1973, No 5.

7. Kantor, L. Ya. et al. Receiving-transmitting satellite complex "Gradiyent", Elektrosvyaz', 1975, No 1.

8. Fortushenko, A.D. et al. Osnovy tekhnicheskogo proyektirovaniya sistem svyazi cherez ISZ [Fundamentals of technical planning of satellite communications systems], Moscow, "Svyaz'", 1970.

9. Bykov, V.L., Borovkov, V.A., "Ekran" ground-based transmitter, Elektrosvyaz', 1977, No 5.

10. USSR Patent No. 560363. FM signal dispersion device. Inventors: Ignatkin, V.S., Shavdiya, Yu. D.

11. Kantor, L. Ya. et al. "Moskva" satellite TV broadcasting receiver, Elektrosvyaz', 1980, No. 1.

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"MOSKVA" SYSTEM RECEIVING STATION

Moscow ELEKTROSVYAZ' in Russian No 1, 1980 pp 10-15

[Article by L. Ya. Kantor, E. I. Kumysh, B. A. Lokshin, A. M. Pokras, A. V. Sokolov, V. M. Tsirlin, I. S. Tsirlin and Ye. Ya. Chekhovskiy, submitted 5 Sep 79]

[Text] Introduction

The "Moskva" sytem receiving station provides reception from "Gorizont" type artificial Earth satellites of one central color TV channel with synchronized audio and one radiobroadcast station. Signal transmission from the satellite is accomplished by frequency modulation (FM) in the 4 GHz range. The received signal is amplified, transformed and enters a local TV center, low-output TV retransmitter or cable distribution network.

The use of an increased output and antenna with narrow beam pattern on a geostationary artificial Earth satellite made it possible to simplify and reduce the cost of the "Moskva" receiving station as compared with the "Orbit" station of similar purpose [1]. Because of the sharply increased energy potential in the satellite-Earth sector, it was possible to greatly reduce the bulkiest part of the station—the antenna system—and switch from antennas with a reflector diameter of 12 meters to simple, inexpensive antennas 2.5 meters in diameter.

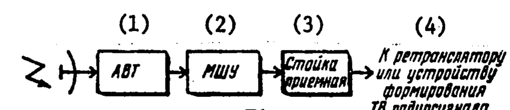

Figure 1

Key: 1. antenna-waveguide tract
2. low-noise amplifier
3. receiving mast
4. to retransmitter or TV signal shaper

Basic Technical Specifications of the Station

Frequency band 3,675 ± 17 MHz; rated input signal level 118 dBW; net total noise temperature at 5° elevation no more than 200 K; energy Q 14.5 dB/K; signal/weighted noise ratio in image channel at least 53 dB. Parameters of sound sync and radio channels meet the norms for Class I channels; power supply 220 VAC ± 10% 50 Hz ± 2 Hz, power consumption (without retransmitter) 500 V.A.

Structural diagram of the "Moskva" station is shown in Figure 1. The signal received by the antenna is fed along the antenna-waveguide tract AWT to the input of a low-noise parametric amplifier (LNA) where the signal is preamplified with a low level of inherent noise. From the output of the LNA the signal is fed through cable to the receiving mast where the SHF [microwave) signal is converted to 70 MHz IF, is amplified and the total FM signal is demodulated. From the output of the receiving mast the image signals, with peak-to-peak amplitude of 1 V ± 10% and audio sync at 0.775 V enter the subscriber distribution device. The station can also contain a 1.10 or 100 W TV retransmitter or a device for operation on a cable network.

The antenna of the receiving station is based on a series produced parabolic reflector 2.5 meters in diameter. The angular dimension of the aperture is 160°, focal length of the reflector is 750 millimeters. To reduce the level of side lobes, the reflector feeds in a single-reflector mode to assure minimum shadowing of the aperture by the feed; the level of feed of the reflector edges is reduced to 16 dB. Antenna gain at 3,675 MHz is 37.5 dB (surface utilization factor 0.61); the width of the beam pattern is 2.2°; the level of the first side lobes is no greater than -20 dB when the feed is in central position.

For reception from the satellite of a circularly polarized signal, a conical bifilar logarithmic helix is used which is powered by a coaxial half-wave symmetrizing device. Alignment of the latter with the coaxial section of the feeder is accomplished by a stepped transformer. A coaxial-waveguide interface is inserted at the junction of the coaxial and waveguide portion of the feeder. To adjust alignment, there are capacitive probes whose depth of insertion is selected during tuning. The antenna is located on a welded metallic pedestal which provides initial orientation of the reflector axis to within 0.5° elevation within the limits of 0-60° and in azimuth to within ± 7.5°. The pedestal is set on a base oriented toward the satellite at a distance no further than 3-4 meters from the technical building. It is also possible to install the antenna on a roof. The antenna and pedestal weigh no more than 400 kilograms.

Antenna-Waveguide Tract

The signal is fed from the antenna to the receiver along a waveguide tract which contains the following: a section of flexible elliptical waveguide 5-7 meters in length, hermetic sealing insert, directional coupler to feed monitoring signals, hermetic seal into the building and a set of angle adapters used in laying out the waveguide. To protect the LNA against overloading by powerful signals of proximite transmitters operating in contiguous frequency bbands, the AWT sometimes has a wideband waveguide filter. The use of a flexible waveguide greatly simplifies the AWT and makes it possible to carry out the initial installation and adjustment of antenna position without disconnecting it. AWT attenuation does not exceed 0.4 dB, SWR is no more than 1.2 in the 3,675 MHz ± 25 MHz band.

The AWT is hermetically sealed against moisture and is under excess pressure. A device is used to maintain the cables under pressure in the capacity of a dehydrating device. Compressed air comes from a tank through a reducing valve into the drying chamber and then through a connecting piece of the hermetic insert into the waveguide tract.

The low-noise parametric amplifier, specially developed for the receiving station of the "Moskva" system, successfully combines high electrical and operating characteristics: low noise temperature, high reliability, low weight and dimensions, minimum number of controls, ability to operate inside or outside of a building. The LNA provides effective noise temperature of no more than 90 K in the 3.5-4.0 GHz band with minimum gain of 30 dB.

The LNA produces this relatively low noise tempeerature by using one stage of the parametric amplifier (PUs) and a low-noise transistor amplifier (TUs). The PUs is a double-loop amplifier of the reflector type with a compensation loop in the signal circuit. In design, the PUs unit is a coaxial waveguide with a coaxial signal input and waveguide excitation input. The pumping generator contains a Gunn diode master oscillator, stabililized by a high-Q Invar resonator, a varactor frequency splitter and an automatic pumping output control system. The TUs is designed to amplify SHF signals after the PUs. It is built on a single clock circuit and contains four stages composed of hybrid ICs. The TUs has gain of at least 20 dB with a noise coefficient less than or equal to 5.5 dB.

The LNA is made in the form of two units: amplification and power supply, connected by a 10 meter long conduit. The amplifier unit is hermetically sealed and is filled with an inert gas. For stabilization of its performance in the range of operating temperatures, within the unit temperature is maintained with a thermal control system from 10 to 25°C. The thermal control sytem contains a thermopile, temperature sensor and control device. The principle of operation of the system is based on the Peltier effect. When temperature within the unit drops below +5°C, the control device sends a feed voltage of that polarity to the thermopile, which heats up the latter. When temperature rises above +30°C, the voltage polarity is reversed and the thermopile and the entire unit cools down. When ambient temperature changes within the limits of -50 to +50°C, LNA amplification is changed by less than 3 dB.

Overall dimensions of the amplification unit are 280 x 260 x 220 millimeters, weight about 12 kilograms. The power supply unit has overall dimensions of 490x 360 x 175 millimeters, and weighs 12 kilograms.

The receiving bench performs the functions of converting SHF signals into IF, amplifying them, demodulating the total signal, discriminating and demodulating the audio sync subcarrier of TV and radio signals. The structural diagram of the bench is shown in Figure 2. A signal, preamplified by the LNA, enters the frequency conversion unit PrCh, where it is converted to standard IF of 70 MHz. At the input of the unit is connected a bandpass filter PF of the counter-rod type which provides the necessary selectivity in the reflection and adjacent receiving channels. The mixer Sm is a balance circuit using Schottky diodes and has a strip design. The preamplification of the IF signal is accomplished by a low-noise three-stage IF amplifier UPCh which is structurally superimposed with the mixer in a common housing. The coefficient of transmission of the PrCh unit is 25 dB, and the noise coefficient is no more than 13 dB.

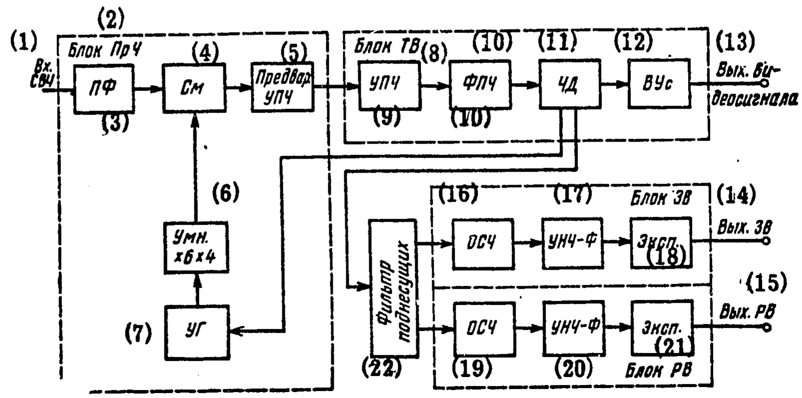

Figure 2

Key:
1. SHF input
2. PrCh unit
3. PF
4. Sm
5. UPCh preamplifier
6. Multiplier x 6 x 4
7. UG
8. TV unit
9. UPCh
10. FPCh
11. ChD
12. VUs
13. Video signal output
14. ZV output
15. RV output
16. OSCh
17. UNCh-F
18. Exp.
19. OSCh
20. UNCh-F
21. Exp.
22. Subcarrier filter

The heterodyne signal source in the PrCh unit is a transitor-varactor circuit consisting of a two-stage power amplifier and two high-rate varactor frequency multipliers (x 6 and x 4) using charge storage diodes. The special configuration of the matching circuits [2] made it possible to achieve high multiplication efficiency in a relatively wide frequency band. To the input of the transistor-varactor circuit is fed a signal with a voltage of 0.8 V from the transistorized master oscillator, whose frequency may be changed within lmits of 150.2 MHz $\pm$ 0.15 MHz in reaction to a control signal from the ChD output.

The need for such control results from the fact that satisfaction of IFRB standards for permissible output flux density near the Earth's surface in the 4kHz band [3] in the "Moskva" system's transmitting station require an additional frequency modulation of the signal by sawtooth voltage with a frequency much lower than that of the TV signal's field. This modulation provides scattering

An escape from this situation is found by using deep degenerative feedback in dispersion signal frequency. The feedback signal is fed from the output of the frequency detector to the variable oscillator (UG) through the d.c. amplifier and low frequency filter, which eliminates feedback in the video signal band. To increase stability of average frequency, the UG is placed in a thermostat in which a temperature of +50 $\pm 1^{o}$C is maintained.

From the output of the PrCh unit the signal enters the television unit TV. Here are accomplished amplification, filtration and demodulation of the FM IF signal, as well as amplification of the video signal to the desired level.

The unit has the following basic technical specifications: nonuniformity of amplitude-frequency characteristic (AChKh) of the tract before the ChD input no more than 0.3 dB in the band 70 $\pm$ 12 MHz and 1 dB in the band 70 $\pm$ 17 MHz; selectivity for the adjacent channel at least 20 dB with the signal detuned by $\pm$ 25 MHz with respect to the frequency of 70 MHz; differential amplitude and differential phase distortions of the TV signal no more than 5 percent and 5^{o}, respectively; nonuniformiy of AChKh at video frequency no greater than 0.5 dB in the band 50 Hz-6 MHz.

The TV unit contains the following series-connected panels: wideband IF amplifier (UPCh), bandpass filter with phase corrector (FPCh), FM demodulator (ChD) and video amplifier (VUs). Use of modern semiconductor components and optimum circuit solutions made it possible to make each panel in the form of a compete functional unit; this greatly simplified tuning and operation of the unit, provided it with high quality indicators and reduced the number of panels used as comoared with the similar "Orbita" and "Ekran" equipment [1, 4].

The UPCh panel is a wideband resistive amplifier with automatic amplification control system containing five identical amplification stages with gain of 12-14 dB each. The amplification stage consists of two npn transistors with common collector/common emitter connections with deep degenerative feedback which guarantees its wide band and almost eliminates the effect of ambient temperature on the technical parameters of the stage. Change in gain of UPCh is carried out by variable attenuators connected between the amplification stages and the two series-connected control diodes. Change in differential resistance of the diodes is done by a signal of the detector ARU.

As a bandpass filter is used a Cauer fifth order filter with bandpass of 34 MHz at a level of -1 dB. Correction of the characteristics of group delay time (GVZ) of the filter is done by a two-link phase corrector which permits a reduction in irregularity of the GVZ to 1 nanoseconds in the band 70 $\pm$ 12 MHz and to 5-7 nanoseconds in the band 70 $\pm$ 15 MHz.

The receiver uses a standard frequency detector as the simplest, most economical and reliable in operation. It contains a two-stage wide band limiter, each stage of which is a limiter of the series-parallel type. The limiter stages are separated by the band filter which efficiently suppresses harmonics of the signal which occur during limit operation. The frequency discriminator is made of detuned circuits and assures high linearity of the demodulation characteristics in the band of frequency deviations 70 $\pm$ 25 MHz. Losses in ChD noise immunitiy with respect to potential do not exceed 1 dB.

In the VUs panel, the audio sync and radio signal frequency subcarriers are suppressed by a rejection filter. The video signal is amplified to one volt and its initial frequency spectrum is recovered. The VUs panel includes a image signal constant component recovery circuit which also provides additional suppression of the dispersion signal.

Audio sync and radio signals in the "Moskva" system are transmitted by frequency modulation on 7.0 and 7.5 MHz subcarriers, respectively.

Audio sync and radio broadcast subcarrier signals are sent through the bandpass filter to the audio units Zv and radio broadcast unit RV of the receiving bench. In the Zv and RV units there are threshold-reducing demodulators with frequency feedback (OSCh) which reduce the demodulation threshold of audio signals by 6-7 dB as compared to a standard demodulator and accordingly reduce the load of each tract with subcarrier signals.

The structural diagram of the OSCh is shown in Figure 3. The signal of the subcarrier with central frequency of 7.0 (or 7.5) MHz and deviation of ± 150 kHz is passed through the bandpass filter PF_1 into the mixer (Sm); to the second intput of the mixer is fed a signal from the FM oscillator (ChMG); it is controlled by a signal from the output of the ChD. With the aid of the bandpass filter PF_2, at the output of the mixer is discriminated a difference signal with a frequency of 2 MHz and deviation of about 30 kHz. Therefore, the FM signal entering the ChD has much less frequency deviation, permitting a corresponding reduction in the noise band of the filter and reducing the frequency demodulation threshold.

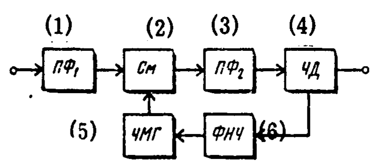

Figure 3

Key:
1. PF_1
2. Sm
3. PF_2
4. ChD
5. ChMG
6. FNCh

The further demodulated siganl is filtered and amplified in the UNCh-F unit, and is then fed to the initial frequency spectrum recovery devices (recovery loop) and dynamic range recovery (expander, Exp). The use of a variable compander permits a gain in the signal/noise ratio at the output of the channel of 15 to 18 dB [5]. For transmission of a control signal proportional to the envelope of the initial signal, a separate narrow band channel is used whose frequency (11,000 ± 125 Hz) is selected outside the band of transmitted frequencies. In the expander, the total signal is separated into basic and control by means of l-f and bandpass filters. The variable element of the expander remultiplies the compressed signal by its envelope and thus recovers the initial dynamic range of the audio signal.

According to the basic quality indicators, the audio sync and radio channels meet the requirements for Class I channels, and in some parameters (irregularity of AChKh), satisfy norms for a higher channel class. Deterioration in the signal/weighted noise ratio in the image channel due to organization of two audio channels is no more than 1.5 dB.

To assure reliable operation of the station without maintenance personnel over the long run, a station version was developed with 100 percent ready reserve equipment. Emergency signals enter the reserve device from sensors in the LNA and at the output of the receiving bench. When excitation output decreases or sync pulses vanish, automatic switching occurs to the reserve set up using a waveguide input selector and the switches "video", "audio", "broadcast", "track" in the output. Retransmitter reserve is accomplished independently of the LNA and receiving bench.

In order to increase reliability in long-term operation without maintenance personnel, the receiving station may use a simplified automatic following system. With slow and small angular translations of artificial Earth satellites, which is typical of satellites in geostationary orbit, the automatic following system is simplest to realize based on the method of extreme control. A dual coordinate extreme automaton performs a sequential search for the extreme along two coordinate axes.

The signal from the output of the amplitude detector of the PCh tract of the receiving bench enters the input of the analog-digital converter (ATsP). At the output of this device is formed a train of semi-meaningful binary combinations corresponding to the level of the signal being received. To increase the noise immunity of the automatic following system, it uses digital integration accomplished by averaging 1,204 readouts of the incoming signal. The time of integration may range from 2 seconds to 0.5 hours. In a comparator are compared the results of digital integration at two adjacent time intervals. As a result, at the output of the comparator appears one of three possible signals: "more", "less" or "equal". These signals enter the logic circuit which, according to the train of signals entering its input, shapes the control signals for the tracking mechanism.

The operational algorithm of the logic unit is depicted in the graph shown in Figure 4. If the logic unit, which actually is a simple processor, is in cycle 1, it shapes instructions which disconnect the electric drive. In this cycle, the interval of integration defined by the rate of angular translation of the artificial Earth satellite, is rather large (up to 0.5 hours). A shift to cycle 2 occurs only if a signal "less" has come from the comparator output, which means that the level of the incoming signal has decreased by some preset quantity. In cycle 2 the drive is disconnected along one of the axes and the beam pattern (DN) of the antenna is deflected one space equal to 15 angular minutes. If the signal has increased (the signal "more" has arrived), the system shifts to cycle 3 and continues to move the beam pattern in the direction of the first space until such time as the signal ceases to increase or does not begin to decrease.

If in the first spacing there has occurred a decrease in the signal's level, the system shifts to cycle 5, where the motor reserves along this axis. After finding the extreme on one axis, similar operations are accomplished on the second axis (cycles 4, 6, 7); then the motors stop and the system shifts to cycle 1, the measurement cycle. To accelerate the search for the extreme, the integration time in cycles 2 thorugh 7 has been reduced to 2 seconds.

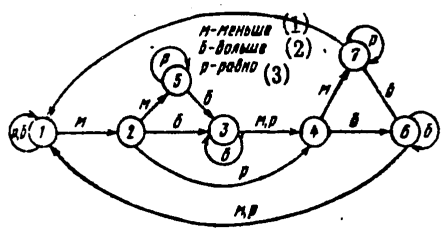

Figure 4
Key: (1) less (2) more (3) equal

The problem of tracking the satellite by the antenna, in view of the small angular translation of the satellite, has been resolved by oscillating the feed in two mutually perpendicular planes. Calculations show that at desired angles of tracking ± 2.5°, feed oscillation should be produced within ± 3°. This displacement of the feed from the focal point causes a loss in antenna gain no more than 0.5 dB and is completely permissible. Irradiator oscillation is done using an electromechanical drive situated on the antenna. The drive contains two identical independent mechanisms for moving the irradiator in azimuth and elevation. Motion is done in steps of 15 angular minutes each, spacing is 1-2 seconds in length. The mechanism operates as follows. The control signal corresponding in polarity from the extreme automaton is amplified by a pulsed transistor amplifier and enters a low-output electric motor, whose rotation is transmitted via a retarding worm gear to the actuator. A Maltese cross intermittent transmission is used to tilt the irradiator.

When the irradiator feed deviates from either extreme position, the end breaker cycles and further motion in this direction is prohibited. To reduce loads on the feed, the latter is connected to an elliptical waveguide by a short cable connector which is structurally situated in the drive housing. Connection of the drive to the extreme automaton is accomplished with a connection cable up to 10 meters in length.

The portable version of the receiving station is designed for operational arrangement of channel reception from central TV in regions where construction of stationary stations is inadvisable or is difficult. It may be used in large edifices, in large-scale geological prospecting teams, in seasonal work areas, as well as to refine the zone of secured reception of the "Moskva" system, measure the zone of interference and study radio wave propagation.

All equipment of the portable station is placed in an ordinary cargo vehicle body which, with the antenna, is attached to a standard low frame trailer chassis.

The radio equipment of the station is similar in makeup to the stationary version. Because of the closer position of the antenna, it was possible to reduce the length of the AWT and signal losses in it, making it possible to reduce the effective noise temperature of the station to 180 K at an elevation of 5°.

Figure 5

To ensure normal operation of station equipment, there are heating, cooling and ventilating systems to maintain ambient air temperature within the cargo vehicle body (KUNG) from 15 to 40°C. The portable station is electrically powered from an AC network as well as from independent power sources aavailable on site. Overall power consumed by the station does not exceed 2-3 kW according to surrounding conditions.

To move the station it is necessary to have a tractor able to trasnport cargo weighing up to 2 tons. Set up time in a preselected area provided with electrical power sources and connection lines is 2-3 hours, and equipment operational readiness time, after feed of power voltages, is no more than one hour.

The receiving station of the "Moskva" system (Figure 5) provides round-the-clock continuous operation without personnel. To install a stationary receiving "Moskva" station it is not necessary to build a special technical building. The equipment may be placed in existing buildings; the required working area (excluding the retransmitter) is no more than 10 square meters.

In conclusion let us note that tests of the first-phase stations under actual conditions corroborated their high technical and operating characteristics.

References

1. Talyzin, N.V. et al. Ground-based "Orbita" station for reception of television channels from artificial Earth satellites. ELEKTROSVYAZ', No 11, 1967.

2. Levkov, B. Yu., Pal'chikovskiy, A.K., Frolov, P.A. Wide band high-rate frequency multipliers in the 0.15-5 GHz range. ELEKTROSVYAZ', No 1, 1978.

3. Kantor, L. Ya. et al. "Moskva" system of satellite television transmission. ELEKTROSVYAZ', No 1, 1980.

4. D'yachkov, V.I., Zevelev, N.M., Kantor, L.Ya., Kumysh, E.I., Petrovskiy, Yu. B., Reushkin, N.A., Sokolov, A.V. "Ekran" system receivers. ELEKTROSVYAZ', No 5, 1977.

5. USSR Patent No. 482904. Variable compander. Inventors: Zaslavskiy, S. A. Khodatay, V.G.

[130-8617]

8617
CSO:1860

Components and Circuit Elements, Including Waveguides, Cavity Resonators and Filters

UDC 621.369.621.3

ASYNCHRONOUS RECTIFIER OF MICROWAVE OSCILLATIONS WITH A VOLUME ELEMENT OF GALLIUM ARSENIDE AT ROOM TEMPERATURE

Moscow RADIOTEKHNIKA in Russian No 1, 1980 pp 56-58 manuscript received 8 Aug 79

[Article by V. A. Malyshev, A. N. Levterov and A. F. Radchenko]

[Text] In [1] results are cited from an investigation of the direct rectification of SHF oscillations in the millimetric wavelength band by means of a volume of gallium arsenide at room temperature. The apparatus described, however, permits one to rectify only SHF outputs of a sufficiently high level (more than 10^{-5}W). Below is shown theoretically and experimentally the feasibility of realizing highly sensitive, asynchronous rectification[2] with the help of an external local oscillator and an n-type volume element of gallium arsenide, the non-linear properties of which depend upon the heating of the charge carriers by a constant electric field which does not attain the threshold voltage U_π, after which a falling region appears in the drift characteristic of the sample.

We will examine a one-dimensional model of asynchronous SHF oscillation rectification by means of a homogeneous volume of semiconductor with ohmic contacts under the influence of an electric field $E(t)=E_0+E_1+E_2$, where E_0, $E_1=A_1\sin(\omega_1 t+\varphi)$ and $E_2=A_2\sin\omega_2 t$ are the strengths of the constant field, the signal and the external local oscillator, respectively. The current density throught the sample on the presence of one type of charge carrier can be represented in the form $j=en(V_0+V_\sim)$, where e is the charge on an electron; n is the concentration of the free carriers, which in SHF can be considered constant; V_0 and $V_\sim$ are the direct and alternating components of the drift velocity of the charge carriers.

In order to determine the average drift velocity $V(t)=V_0+V_\sim$ in the unidirectional direct and alternating electric fields in the case of quasi-electric scattering, we use an equation for heating[3-5]

$$\frac{dW(t)}{dt} = eE(t)V(t) - \frac{W(t) - W_0}{\tau_e(W)} \qquad (1)$$

and an equation for the motion of the charge carriers

$$\frac{dV(t)}{dt} = \frac{eE(t)}{m(W)} - \frac{V(t)}{\tau(W)}, \qquad (2)$$

where W(t) is the average energy of the random motion of the charge carriers; $W_0 = \frac{3}{2}kT$ is the average energy of the phonons, which corresponds to the temperature of the grid T; m(W) is the effective mass; $\tau_e(W)$ and $\tau(W)$ is the average time of relaxation of the energy and the momentum of the charge carriers; k is the Boltzman constant.

As was shown in [4], equations (1) and (2) are valid for double valley point semiconductors (GaAs, for example) in the case of direct current voltages $U<U_\pi$. The solution to the system of non-linear equations in (1) and (2) with reference to W(t) and V(t)--without consideration of the intermediate processes and with the application of an integration procedure according to m(W), $\tau(W)$ and $\tau_e(W)$ upon series expansion[5] of these values in a quasi-linear approximation--allows one to determine the expressions for the direct current component of the current density of direct rectification j_0 when $A_2=0$ and for the current density j_{03} with a frequency $\omega_3=\omega_1-\omega_2$ of asynchronous rectification in the case of $\omega_3 \approx 0$ and $\varphi=0$:

$$j_0 = \frac{en\mu_{01}\varkappa E_0 A_1^2}{2\left(1+y_e^2\right)\beta_1}\left[\frac{\varkappa E_0^2}{\beta_1} p_\tau(p_m+p_\tau)\left(4+y_0^2\right) - p_m\left(2-y_0 y_e+y_0^2\right) - p_\tau(2+y_0 y_e)\right]; \qquad (3)$$

$$j_{03} = \frac{en\mu_{01}\varkappa E_0 A_1 A_2}{\left(1+y_e^2\right)\beta_2}\left[\frac{\varkappa E_0^2}{\beta_2} p_\tau(p_m+p_\tau)\left(4+y_0^2\right) - p_m\left(3-y_e y_e+y_0^2+y_e^2\right) - p_\tau\left(3+y_0^2+y_0 y_e\right)\right]. \qquad (4)$$

where $\mu_{01} = \frac{e\tau_0}{m_0}$ $\varkappa = \frac{\varkappa'}{1+y_0^2}$; $y_0 = \omega_1\tau_0 = \omega_2\tau_0$; $y_e = \omega_1\tau_{0e} = \omega_2\tau_{0e}$; $\varkappa' = \frac{e\mu_{01}\tau_{0e}}{W_0}$; $\beta_1 = 1 + \varkappa'\left[E_0^2 + \frac{A_1^2}{2\left(1+y_0^2\right)}\right]$; $\beta_2 = 1 + \varkappa'\left[E_0^2 + \frac{A_1^2+A_2^2}{2\left(1+y_0^2\right)}\right]$;

m_0, τ_0 and τ_{0e} are the constant values that depend upon the energy of heating of the electrons ; p_m and p_τ are the parameters that determine the change m(W) and $\tau(W)$ upon heating.[5]

From (3) and (4) it follows that the currents of direct and asynchronous rectification conform in sign. From (4) it follows that during asynchronous rectification the function $j_{0s}(A_2)$ possesses a maximum, that is, there exists an optimum value A^2_{OPT} (proportional to the output of the local oscillator P_0), at which j_{0s} is at maximum. At the same time, if we examine the the case of scattering of the charge carriers on optical phonons in polar semiconductors (which takes place, for example, in gallium arsenide[6] when the parameter that determines the scattering mechanism in the lower valley, $p_r=-0.5$), then, taking into account the well executed relation y_0^2, $y_0 y_s \ll 1$ for gallium arsenide in the case of $U<U_\pi$ in the 25-37 GHz range, we obtain

$$A^2_{2\text{опт}} = \frac{2\sqrt{3}}{\varkappa'\left(3+y_s^2\right)} \times$$
$$\times\left[\sqrt{1+2y_s^2+\frac{1}{3}y_s^4+8\varkappa' E_0^2\left[1+\frac{7}{12}y_s^2+\frac{1}{12}y_s^4+\varkappa' E_0^2\left(1+\frac{1}{3}y_s^2+\frac{1}{24}y_s^4\right)\right]}-\sqrt{3}\varkappa' E_0^2\right],$$

from which it can be seen that A^2_{2OPT} decreases with increases in E_0. This is confirmed experimentally. As is seen from (3) and (4), the presence of oscillations in the local oscillator A_2 leads to an acute (approximately A_1/A_2 times) increase in the rectification efficiency of SHF signals.

Experimental research into asynchronous rectification with a volume of semiconductor has been carried out on samples made from epitaxial layers of n-GaAs grown on a heavily doped substrate, whereupon the samples and the design of the rectifier stage are similar to those described in [1]. Direct-current voltage was supplied to the samples through a choking coil $L=0.25\cdot10^{-3}$H, which is the load of the asynchronous rectifier. This load was decoupled with the help of a constructive capacitance (about 5 pF). The rectified voltage was passed from the load into a video frequency amplifier (possessing a passband $\Delta f=20$ MHz and an amplification factor $K_B=200$) and the oscillograph was observed on the screen. Measurements were taken at a frequency of 32 GHz for voltages on the sample $U<U_\pi$. At the same time an external local oscillator was used, the oscillation frequency of which was tuned to the frequency of the signal. The power of the continuous oscillations of the local oscillator P_0 was passed through a ferrite rectifier, while the signal with output P_s possessed amplitude modulation and proceeded to the input of the rectifier stage through a directional coupler. In this case there were observed on the screen of the oscillograph pulses with frequency modulation (about 1 kHz) filled with a beat frequency that did not exceed 1 MHz. Meas-

uring the amplitude of the pulses U_2' on the oscillograph screen one may determine the transfer coefficient $K_\pi=10\ \lg P_c/P_s$, where $P_c=U_2'^2/2R_c$ is the power of the signal ($U_2=U_2'/K_s$) of the asynchronous rectification, distinguished in the load L with resistance R_c (at the beat frequency $\approx 250\ \Omega$). $U_2=j_{03}SR_c$, S is the area of the sample; P_s is the power of the SHF signal entering into the input of the rectifier stage when tuned to the minimum standing wave ration $\approx 1:2$. The dependence of the transfer coefficient K_π upon the local oscillator power P_0/P_{0r} ($P_{0r}=50$ mW) when $P_s=10^{-8}$ W shows (fig. 1) that when $U/U_\pi \geq 0.82$, the optimum values of P_0 occur, at which time K_π is maximum in accordance with the conclusions of the theory. In figure 2 is shown the dependence of the transfer coefficient K_π upon the level of the input signal P_s for a local oscillator output $P_0/P_{0r}=0.6$ (which is optimum when $U/U_\pi=0.8$) in the case of varying values for the direct current voltage.

A comparison of the dynamic ranges of direct[1] and asynchronous rectification (fig. 2) shows that, in the latter case, operation is possible with amplification in a wider dynamic range (from 10^{-11} to 10^{-5} W) which begins from values $P_s=10^{-5}$ W, that is, from the level of tangential sensitivity of the direct rectification. The positive value of K_π is dependent upon the heating of the charge carriers in the volume of GaAs by the direct current voltage and the output of the local oscillator, as a result of which there appears a negative cubic conductance in the sample.[7]

The greatest tangential sensitivity[8] $P_\tau=-90$ dBmW is attained for $U/U_\pi=0.65$ and $P_0/P_{0r}=1$. However, with an increase in the constant field, the local oscillator output necessary for reaching the same sensitivity decreases, whereupon P_τ of the asynchronous rectification with a volume of n-GaAs is significantly higher than that of direct rectification.[1] This sensitivity is comparable to the sensitivity of mixers on point-contact diodes and diodes with Schottky barriers for the same range of wavelengths.[8] At the same time, the asynchronous rectifier makes it possible to exclude an intermediate frequency amplifier, while the utilization of the volumetric properties of the n-GaAs increases the power stability and reliability of the receiving apparatus, on the whole.

The experimental results cited qualitatively confirm the data from the theoretical analysis with respect to the evaluation of the currents of asynchronous and direct rectification of SHF oscillations, so that the relations (3) and (4) obtained make it possible to evaluate, for known parameters p_τ, p_m, μ_{01} and τ_{e0} of the semiconductor, the feasibility of devices employing the indicated rectification.

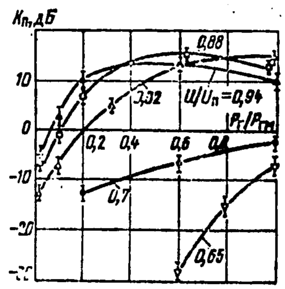

Fig. 1

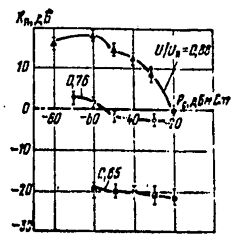

Fig. 2

Although the above-cited measurements of asynchronous rectification are for a signal frequency of 32 GHz, analogous results are obtained for all currents in the band from 25.8 to 37 GHz by retuning the frequency of the external local oscillator and by achieving a maximum value U_2' through shifting the short-circuiting plunger.

The results obtained for the theoretical and experimental research into an asynchronous rectifier made from a volume element of GaAs show the promise of utilizing it as a power stable element for the purpose of sensitive reception of radio-pulsed signals in the millimeter wavelength band.

BIBLIOGRAPHY

1. Malyshev, V. A. and Levterov, A. N. IZVESTIYA VUZOV SSSR, SERIYA RADIOELEKTRONIKA, Vol 22, No 5, 1979.

2. Abramyan, A. A. "Asinkhronnoye detektirovaniye i priyem impul'snykh radiosignalov"[Asynchronous Rectification and Reception of Pulsed Radio Signals], Moscow, Sov. radio, 1966.

3. Gribson, A. F., Granville, I. W. and Paige, E. G. S. JOURN. PHYS. CHEM. SOLIDS, Vol 19, No 3, 1961.

4. Glover, G. H. JOURN. APPL. PHYS., Vol 44, No 3, 1973.

5. Malyshev, V. A. IZVESTIYA VUZOV SSSR, SERIYA RADIOELEKTRONIKA, Vol 22, No 5, 1979.

6. Bass, F. G. and Gurevich, Yu. G. "Goryachiye elektrony i sil'nyye elektromagnitnyye volny v plazme poluprovodnikov i gazovogo razryada" [Heated Electrons and Strong Electromagnetic Waves in a Plasma of Semiconductors and Gaseous Charge], Moscow, Nauka, 1975.

7. Malyshev, V. A. IZVESTIYA SKNTs VSh, SERIYA YESTESTVENNYYE NAUKI, No 1, 1976.

8. Anand, E. and Moroin, V. in "Poluprovodnikovyye pribory SVCh" [Semiconductor SHF Devices], Moscow, Mir, 1972.

[157-9512]

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CSO: 1860

Electromagnetic Wave Propagation; Ionosphere, Troposphere; Electrodynamics

UDC 621.396.6

THE SYNTHESIS OF RANDOMLY DISTRIBUTED SOURCES FOCUSING AN ELECTROMAGNETIC FIELD IN THE CASE OF A GIVEN CURRENT NORM

Moscow RADIOTEKHNIKA in Russian No 1, 1980 pp 49-52 manuscript received 20 Jan 79

[Article by B. G. Belyayev]

[Text] A number of technical problems (wireless energy transmission, cutting through rock by means of microwave field heating, high-resolution radar photography of terrain, the diagnostics of ionized environments, target destruction at great distances from the energy source, etc.) are dependent upon the necessity of solving the electrodynamic questions associated with the focusing of an electromagnetic field.

The synthesis of electromagnetic field sources and a continuous current distribution insuring the maximum field strength at a selected point is examined in a number of works. In [1] the generality of stating the problem was limited by a stipulation that the focus point be located not closer than the limit of the Fresnel approximation, a scalar variant of the problem; in this case the phase shift characteristic of the source was optimized. In [2], in a vector problem, the geometry of the source (circle), the direction of the currents and their maximum values were considered as the given quantities; in this case the amplitude-phase distribution was optimized.

In this paper the geometrical form of the source is not specified, and a slight limitation is imposed upon the focus location by taking it out beyond the region of the field's source. Alongside the amplitude-phase distribution is located the maximum current orientation, which together insure the maximum absolute value for the projection of the electric field vector in focus in a selected direction with a given current norm. Besides that, the optimum power distribution is examined for particular cases of field source location.

Formulating the problem.

The projection onto the unit vector a of the vector of an electric field created by electric and magnetic currents with a volume density of $j^э(Q)$ and $j^м(Q)$, radiated into random space, can be represented at observation point F in the form of an integral[(3), p 54]

$$(Ea) = \int_V \sum_{n=1} (j_n^э E_{on} - j^м H_{on})\, dV_Q; \quad F \notin Q, \qquad (1)$$

where $j_1^{э(м)}, j_2^{э(м)}, j_3^{э(м)}$ are the complex-valued lengths of the vectors $\bar{j}_1^{э(м)}, \bar{j}_2^{э(м)}, \bar{j}_3^{э(м)}$ are the components of vector $j^{эм}$ in a random, orthogonal curvilinear system of coordinates; E_{on}, H_{on} $(n=1;2;3)$ are the complex-valued lengths of the orthogonal components in the foregoing system of coordinates of the vectors; E_o, H_o, determined by the formulas

$$E_o = \frac{1}{4\pi i\omega\varepsilon_a} \operatorname{rot} \operatorname{rot} a \frac{e^{-ikr}}{r}, \quad H_o = \frac{1}{4\pi} \operatorname{rot}_Q a \frac{e^{-ikr}}{r};$$

dV_Q is the element of volume around point Q; r is the distance between points F and Q.

The functions E_o and H_o can be integrated, in particular, as the ratio, respectively, of the strengths of the electric and magnetic fields created by an electric dipole situated at point F and oriented in the direction of a, toward the value of the current moment of the dipole.

The problem of optimizing the current distribution is reduced mathematically to the calculation of the functions $j_n^э$, $j_n^м$, which realize the maximum absolute value of the integral (1) in the case of limitations imposed upon the values of the current norms

$$\|j^э\| = \sqrt{\int j^э j^{э*} dV_Q} = \text{const}_1; \quad \|j^м\| = \sqrt{\int j^м j^{м*} dV_Q} = \text{const}_2. \qquad (2)$$

Solution to the problem of optimization. We will find the optimum phase characteristic of the current by applying to integral (1) an inequality pertaining to the basic properties of of the integrals[(4), p 113]

$$|Ea| \leq \int \sum_{n=1}^{3} (|j_n^э| \cdot |E_{on}| + |j_n^м| \cdot |H_{on}|)\, dV_Q. \qquad (3)$$

It is obvious that the value |Ea| reaches its maximum, determined by the right half of (3), if the phase characteristics of the functions $f_n^э$, $f_n^м$ satisfy the equalities

$$\operatorname{Arg} j_n^э = -\operatorname{Arg} E_{on} + \varphi_o; \quad \operatorname{Arg} j_n^м = -\operatorname{Arg} H_{on} + \pi + \varphi_o; \quad \varphi_o = \text{const}. \qquad (4)$$

Upon fulfilling conditions (4) the problem of further optimizing the current distribution is reduced to the calculation of a system of functions $|f_n^э|$, $|f_n^m|$ which realize the maximum of the integral in the right half of inequality (3) in the presence of coupling equations--limitations on the values of the current norms, that is, it is reduced to an isoperimetric problem of variational calculus. Solving it through known methods we obtain the maximum of integral (3) taking place when

$$|J_n^э| = C_1|E_{0n}|; \quad |J_n^м| = C_2|H_{0n}|, \qquad (5)$$

where C_1 and C_2 are constant coefficients.

We will combine the amplitude (5) and phase (4) characteristics of the current in one notation. Assuming $\varphi_0=0$, we will obtain

$$J_n^э = C_1 E_{0n}^*; \quad J_n^м = -C_2 H_{0n}^*. \qquad (6)$$

Inserting (6) in (2) we find the values C_1 and C_2. Changing to vector notation for the result, we obtain a definitely optimum distribution of currents $j^э$ and j^m in the form

$$\mathbf{j}^э = \frac{\|j^э\|}{\|E_0\|}\mathbf{E}_0^*; \qquad \mathbf{j}^м = -\frac{\|j^м\|}{\|H_0\|}\mathbf{H}_0^*. \qquad (7)$$

If the sources of the field are surface currents $J^э$ and J^m, we will select an orthogonal system of coordinates so that index "3" in (1) corresponds to the coordinates that are normal to the surface S of the distribution of currents. Then projection E focused in the direction of a will be

$$(\mathbf{E}a) = \int_S (J_1^э E_{01} + J_2^э E_{02} - J_1^м H_{01} - J_2^м H_{02})\, dS. \qquad (8)$$

The variational analysis (8) is analogous to the analysis of integral (1). Further noting that $E_{01}+E_{02}$ and $H_{01}+H_{02}$ are the tangential components of vectors E_0 and H_0, tangent to surface S, we find in analogy to (7) the optimum distribution of the surface current in the form

$$\mathbf{J}^э = (\|J^э\| : \|E_{0k}\|)\, E_{0k}^*; \quad \mathbf{J}^м = -(\|J^м\| : \|H_{0k}\|)\, \mathbf{H}_{0k}^*. \qquad (9)$$

In the case of linear currents the optimum distribution is likewise expressed by formula (9), where one should conceive of the projection of vector $E_0(H_0)$ on the current's distribution path only as $E_{0k}(H_{0k})$.

From (7) and (9) it follows that the optimum current distribution coincides in amplitude characteristic and direction with that field strength which would have been created in the region of the sources' location by a dipole situated at the focus point, while the optimum phase characteristic is a complex conjugate with reference to the phase characteristic of the dipole's field.

In an individual case when the sources possess the form of linear currents the problem of optimization can be limited to the optimization of the amplitude-phase distribution only. Further applying the reciprocity theorem, which establishes a linear link between the directional diagram of the element of current in the direction of point F and the magnitude of E_{0k} at the point of distribution of this element of current, we will find that the optimum current value on a selected element of length can be treated as a value proportional to the value of the complex conjugate of the directional diagram of this element of current, determined in the direction of point F. An analogous result was obtained earlier [5], p 106] in solving the problem of maximizing the directional gain of a system of linear sources without consideration of their mutual influence (for observation points located in a distant zone).

The power of the optimum distribution. Rationalizing the expression for the dependence of the radiation power of electric current upon the current distribution function. We will discover a link between the field strength at the focal point and the active radiation power of an electric current possessing an optimum distribution in accordance with formula (9). In the process of solving this problem we convert the formula for the calculation of the active and reactive portions of power into a new form which simplifies the calculation of the power and the analysis of the dependence of its value upon the form of the functions which describe the distribution of the electric current.

The complex radiation power P· of an electric current, as is well known,[6], p 16] is equal to

$$P^{\cdot} = -\frac{1}{2}\int \mathbf{j}^{*}(Q)\,\mathbf{E}(Q)\,dV_Q. \qquad (10)$$

Inserting into (10) the expression for field E, valid for the source [7], we will obtain

$$P^{\cdot} = -\frac{1}{8\pi i k} W \iint [k^2 \mathbf{j}^{*}(Q)\,\mathbf{j}(Q') - (\mathrm{div}_{Q'}\,\mathbf{j}(Q'))\,\mathbf{j}^{*}(Q)\,\mathrm{grad}_{Q'}\psi]\,dV_Q\,dV_{Q'}, \qquad (11)$$

where $\psi = e^{-ikr_{QQ'}}/r_{QQ'}$; $W = \sqrt{\mu_0/\varepsilon_0}$.

Through integration by parts of the expression $\mathbf{j}^*(Q)\,\mathrm{grad}_{Q'}\psi dV_Q$ we reduce (11) to the form

$$P^{\cdot} = -\frac{1}{8\pi ik} W \iint \psi L(\mathbf{j})\, dV_Q dV_{Q'}, \qquad (12)$$

where $L(\mathbf{j}) \equiv k^2\mathbf{j}^*(Q)\,\mathbf{j}(Q') - \mathrm{div}\,\mathbf{j}^*(Q)\,\mathrm{div}\,\mathbf{j}(Q')$.

We change the places of points Q and Q' in (12) and combine the expression obtained with formula (12). As a result we have for the active power

$$\mathrm{Re}\, P^{\cdot} = \frac{1}{8\pi} W \iint \frac{\sin kr_{QQ'}}{kr_{QQ'}} \mathrm{Re}\, L(\mathbf{j})\, dV_Q dV_{Q'}, \qquad (13a)$$

from which it likewise follows that

$$\mathrm{Re}\, P^{\cdot} = \frac{1}{8\pi} W \iint \frac{\sin kr_{QQ'}}{kr_{QQ'}} L(\mathbf{j})\, dV_Q dV_{Q'}. \qquad (13b)$$

The expression for the reactive power is obtained by replacing the function $\sin kr_{QQ'}$ by $\cos kr_{QQ'}$ in the right half of formulas (13a) and (13b).

The integration in (13) is carried out throughout the entire space. If the current function examined on an unbounded region has the form of a discontinuous function, then operation div forms δ-functions at the points of discontinuity of the current function. If the sources are given in the form of surface currents, then instead of div in (13) it is necessary to insert div [2] or n rot [n, J] (where n is the unit vector normal to the surface of the current distribution J).

Formula (13) offers a new expression for the radiation power of an electric current which facilitates the analysis of the power's dependence upon the form of the function for the current distribution and the analysis of the mutual influence of spaced antennas. For example, one may contrast formula (13b) with the notation <i[r]i*>, cited in [6] (p 252), which expresses the active radiation power of a system of discrete sources. One may utilize formula (13b) to calculate the mutual resistance matrix [r].

The representation of the power in the form (13) is valid for currents given in the form of random-type functions. Proceeding to the distribution of the electric current given in the form (9) we will notice that this distribution can be considered to be little variable over the wavelength, if it has been stipulated that the focus point is removed from the nearest source point by a distance exceeding 10 wavelengths. Assuming further that the field sources have the form of surface currents and that the diametrical dimensions of the surface S of the currents' distribution are much greater than a wavelength, we will find from (13) a simpler approximate expression for the active radiation power

$$P \equiv \mathrm{Re}\, P^{\cdot} \approx \frac{1}{4} W \int \mathbf{J}\mathbf{J}^{*} dS_Q + 0\left(\frac{1}{k}\right) \equiv \frac{1}{4} W \| J \|^{2} + 0\left(\frac{1}{k}\right). \qquad (14)$$

It follows from (14) that under the stipulated conditions the active portion of the radiation power hardly changes with fluctuations in the current distribution if, at the same time, the value of the current norm is maintained.

We will find the field strength at the focus point with an optimum distribution of the surface current J, by inserting in formula (1) the current distribution in accordance with (9). Then we will obtain

$$(\mathbf{E}a) = \int_{S} \| J^{э} \| \frac{1}{\| E_{0k} \|} \mathbf{E}^{*}_{0k} \mathbf{E}_{0k} dS_Q = \| J^{э} \| \cdot \| E_{0k} \|. \qquad (15)$$

Taking (14) into account, (15) assumes a form that shows the dependence of the field strength at the focus point upon the radiation power of the focusing sources

$$(\mathbf{E}a) = \sqrt{\frac{4P}{W}} \| E_{0k} \|. \qquad (16)$$

Radiation of the field distribution in the vicinity of the focus is possible only with a specific definition of the location of the sources. For an individual case--the arrangement of the sources in the form of electric surface currents on a sphere--an analysis of the field in the vicinity of the focus is given in (9).

Conclusion. The distribution of the exciting currents that we have found is not strictly optimum from a power point of view. In order to find the current distribution which insures focusing with minimum power losses and which possesses a realizable level of reactance, it is necessary during the search for the current functions which impart a maximum to the integral (1), except for setting the current norm (3), to fix again the magnitude of the radiation power (in other words, to solve the problem with a given reactance or with the so-called bounded norm of solution[8]). An analytical solution to such a problem has not been found up until now. However, for a linear source of isotropic radiations it has been shown[6], p284,[8] that the distributions with an increased, but realizable, norm of solution essentially improve the efficiency of only small-dimensioned antennas which do not exceed several wavelengths. In practice it is the large focusing systems which are of much greater interest.

In this connection, a certain practical interest is presented by the distribution found in (9), which takes (14) into account. This distribution has a simple analytical form no matter how complex the body on which the current distribution is examined.

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BIBLIOGRAPHY

1. Bicmore, R. W. CAN. J. PHYS., Vol 35, No 11, 1957.

2. Belyayev, B. G. "Questions on the Interaction of Electromagnetic Waves With Matter," TRUDY MEI, Vol 194, 1974.

3. Fradin, A. Z. "Antenny sverkhvysokikh chastot" [SHF Antennas], Moscow, Sov. radio, 1957.

4. Korn, G. and Korn, T. "Spravochnik po matematike" [Handbook for Mathematics], trans. from English, Moscow, Sov. radio, 1968.

5. Vendik, O. G. "Antenny s nemekhanicheskim dvizheniyem lucha" [Antennas With Non-Mechanical Movement of the Beam], Moscow, Sov. radio, 1956.

6. Markov, G. T. and Sazonov, D. M. "Antenny," Moscow, Energiya, 1975.

7. Belyayev, B. G. IZVESTIYA VUZOV. RADIOFIZIKA, Vol 15, No 6, 1972.

8. Tartakovskiy, L. B. RADIOTEKHNIKA I ELEKTRONIKA, Vol 3, No 12, 1958.

9. Belyayev, B. G. IZVESTIYA VUZOV. RADIOTEKHNIKA I ELEKTRONIKA, Vol 22, No 2, 1979.

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General Production Technology

CHEMICAL PROCESSING AND PHOTOLITHOGRAPHY IN THE PRODUCTION OF SEMICONDUCTOR DEVICES AND MICROCIRCUITS

Moscow KHIMICHESKAYA OBRABOTKA I FOTOLITOGRAFIYA V PROIZVODSTVE POLUPROVODNIKOVYKH PRIBOROV I MIKROSKHEM in Russian 1979 pp 2, 271-272 signed to press 18 Jan 79

/Annotation and Table of Contents from the book by Oleg Konstantinovich Mokeyev and Aleksandr Sergeyevich Romanov, 9,000 copies, 272 pages/

/Text/ The textbook examines the technological processes of chemical processing, photolithography, and phototemplate manufacture in the production of semiconductor devices and integrated microcircuits. The bases of the theory of these processes, the methods and means of quality control of the processing, and technological operations and equipment are discussed.

Contents

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Communications, Communication Equipment, Networks, Radiophysics, Data Transmission and Processing

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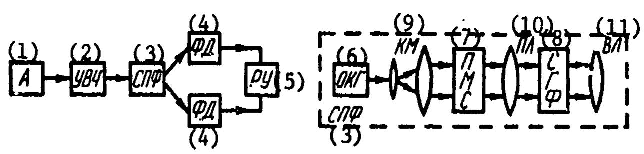
INTERFERENCE IMMUNITY OF ELECTRONIC SYSTEMS WITH OPTICAL SIGNAL PROCESSING

Kiev IZVESTIYA VUZov: VYSSHIKH UCHEBNYKH ZAVEDENIY in Russian No 1, 1980 pp 71-73

[Article by A. T. Serobabin and E. V. Borisov]

[Text] In the cited literature [Ref. 1-4] insufficient attention has been given to problems of optically matched filtration in the object region. In this paper, an estimate is made of the interference immunity of binary radio receivers with this kind of signal processing. Such estimates are of practical interest, and to our knowledge have not been previously published.



a b

Fig. 1

KEY:
1--*А* = antenna
2--*УВЧ* = rf amplifier
3--*СПФ* = matched spatial filtration unit
4--*ФД* = photodetector
5--*РУ* = resolver
6--*ОКГ* = laser
7--*ПМС* = spatial light modulator
8--*СГФ* = matched holographic filter
9--*КМ* = collimator
10--*ПЛ* = converting lens
11--*ВЛ* = restoring lens

One of the possible ways to make the receiver is shown in Fig. 1a. It includes an antenna (1), rf amplifier (2), matched spatial filtration unit (3), two photodetectors (4) and a resolver (5). Fig. 1b shows the spatial filtration unit, which contains a series hookup of a laser (6), collimator (9), spatial light modulator (7), converting lens (10), matched holographic filter (8) and restoring lens (11).

The received additive signal-noise mixture goes to the input of the spatial light modulator, where the time signal is converted to the space analog, which is the initial signal for modulation of the light field emitted by the laser. The resultant light signal at the output of the spatial light modulator has the form [Ref. 1]:

$$E(x) = E_0 \exp\{j\omega_{с+ш}(x)\},$$

where $\omega_{с+ш}(x) = \omega_с(x) + \omega_ш(x)$; $\omega_с(x) = \frac{\beta}{\lambda} U_с \alpha_с(x)$ is the spatial phase of the signal; $\omega_ш(x) = \frac{\beta}{\lambda} U_ш(x)\alpha_ш(x)$ is the spatial phase of the noise; β, λ are the phase modulation index and wavelength of the laser emission; $U_С$, $U_Ш$ are the signal amplitude and noise amplitude respectively; $\alpha_С$, $\alpha_Ш$ are angle functions of the optical image of signal and noise respectively; x is the spatial coordinate in the plane of the spatial light modulator.

At high signal-to-noise ratios, the probability density of instantaneous values of the random quantity $\omega_{С+Ш}$ will obey a normal law with mathematical expectation $\omega_С$ and dispersion $\beta^2\sigma_Ш^2$, where $\sigma_Ш^2$ is the noise dispersion at the input of the spatial light modulator.

In the plane of the photodetector, the amplitude of the filter response to the arriving perturbation is

$$E(\xi) = F\{E(x)\tau(x)\},$$

where $\tau(x) = \tau_0 + \Delta\tau \cos[\omega_{0С}(x) + \omega_0 x]$ is the amplitude transmission factor of the matched holographic filter; τ_0 is the average amplitude transmission; $\Delta\tau$ is the amplitude of the change in transmission; $\omega_{0С}(x)$, $\omega_0 x$ are the spatial phases of the signal and of the reference wave on the stage of recording of the matched holographic filter; F is the Fourier transform operator; ξ is the spatial coordinate in the plane of the photodetectors.

Then the average amplitude of the field in the plane of the photodetectors upon arrival of the matched signal is

$$\bar{E}_с(\xi) = \frac{E_{0\Delta}\tau}{2} L e^{-2\pi^2\sigma^2_{с+ш}} \frac{\sin \frac{\pi L}{\lambda F_л}(\xi - \lambda F_л \omega_0)}{\frac{\pi L}{\lambda F_л}(\xi - \lambda F_л \omega_0)},$$

while in the case of an unmatched signal

$$\bar{E}_{нс}(\xi) = \frac{E_{0\Delta}\tau}{2} L e^{-2\pi^2\sigma^2_{с+ш}} J_0(2\beta) \frac{\sin \frac{\pi L}{\lambda F_л}(\xi - \lambda F_л \omega_0)}{\frac{\pi L}{\lambda F_л}(\xi - \lambda F_л \omega_0)},$$

where L is the spatial extent of the signal; $F_Л$ is the focal length of the restoring lens; J_0 is a zero-order Bessel function of the first kind.

If the diameter of the photodetector is selected as equal to the diameter of the diffraction-limited spot $2\frac{\lambda F_\lambda}{L}$, then the mathematical expectation of the current at the output of the photodetector in the case of reception of a matched signal is

$$\bar{i}_c = \frac{1}{2} E^2_{э\phi c} D = \frac{1}{2} D \left[\frac{E_{0\Delta}\tau}{2} L e^{-2\pi^2\sigma^2_{c+ш}} \frac{1}{2\pi} \int_{-\pi}^{\pi} \frac{\sin z}{z} dz \right]^2, \quad (1)$$

and for reception of an unmatched signal

$$i_{нc} = \frac{1}{2} E^2_{э\phi нc} D = \frac{1}{2} D \left[\frac{E_{0\Delta}\tau}{2} L e^{-2\pi^2\sigma^2_{c+ш}} J_0(2\beta) \frac{1}{2\pi} \int_{-\pi}^{\pi} \frac{\sin z}{z} dz \right]^2, \quad (2)$$

where $E_{э\phi} = \frac{L}{2\lambda F_л} \int_{-\frac{\lambda F_л}{L}}^{\frac{\lambda F_л}{L}} \bar{E}(\xi) d\xi$ is the effective amplitude of the field, and D is the conversion factor of the photodetector.

For the case of a binary channel, the average probability of erroneous signal reception is defined by the relation

$$P_{ош} = \int_{-\infty}^{\infty} P(i_c) \int_{i_c}^{\infty} P(i_{нc}) di_{нc} di_c. \quad (3)$$

In the strong-signal case, the current conforms to normal distribution at the input of the photodetector [Ref. 5]. With consideration of this fact, relation (3) can be converted by substitution of the variable of integration to the form

$$P_{ош} = \frac{1}{2\sqrt{\pi}} \int_{-\infty}^{\infty} e^{-z^2} \operatorname{erfc}\left[z \frac{\sigma_{ic}}{\sigma_{iнc}} + \frac{\bar{i}_c - \bar{i}_{нc}}{\sqrt{2}\,\sigma_{iнc}} \right], \quad (4)$$

where $\sigma_i = 2\bar{i}_\Delta f e$; $\operatorname{erf} c = \frac{2}{\sqrt{\pi}} \int_z^{\infty} e^{-t^2} dt$; e, Δf are electronic charge and the photodetector passband.

Substituting (1) and (2) in (4), we get:

$$P_{ош} = \frac{1}{2} \operatorname{erf} c \left[B \frac{1 - J_0^2(2\beta)}{\sqrt{1 + J_0^2(2\beta)}} \right],$$

where

$$B = \frac{E_0\Delta\tau}{2} L e^{-2\pi^2\sigma^2_{c+ш}} \frac{1}{2\pi} \int_{-\pi}^{\pi} \frac{\sin z}{z} dz.$$

The resultant expression can be used to evaluate the interference immunity of reception of binary radio signals in devices with optical processing. The results of calculations of the average error probability are given in Fig. 2.

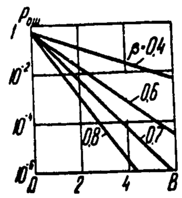


Fig. 2

REFERENCES

1. G. S. Kogerentnymi, "Obrabotka informatsii kogerentnymi opticheskimi sistemami" [Data Processing by Coherent Optical Systems], Moscow Sovetskoye radio, 1975.

2. S. B. Gurevich, editor, "Opticheskiye metody obrabotki informatsii" [Optical Methods of Data Processing, Leningrad, Nauka, 1974.

3. G. I. Vasilenko, "Golograficheskoye opoznavaniye obrazov" [Holographic Pattern Recognition], Moscow, Sovetskoye radio, 1977.

4. L. M. Soroko, "Osnovy golografii i kogerentnoy optiki" [Principles of Holography and Coherent Optics], Moscow, "Nauka", 1971.

5. A. G. Sheremet'yev, "Statisticheskaya teoriya lazernoy svyazi" [Statistical Theory of Laser Communications], Moscow, Svyaz', 1971.

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INTERFERENCE IMMUNITY OF ELEVATION AND FREQUENCY DIVERSITY-SPACED RECEPTION OF SIGNALS IN A CHANNEL WITH CONCENTRATED INTERFERENCE

Moscow RADIOTEKHNIKA in Russian No 1, 1980 pp 43-48 manuscript received 1 Nov 78

[Article by P. V. Belov and V. I. Orlov]

[Text] This analysis of the interference immunity of SW signal reception in a reception system utilizing elevation and frequency diversity spacing, under conditions in which the band is loaded with concentrated interference, has been carried out on the basis of a known interference model [1]. The interference flux is described with respect to elevation and frequency by means of a two-dimensional Poisson flux with intensity α, 1/degrees for the elevation and β, 1/kHz for the frequency. The power spectrum of each disturbance is characterized by the number of beams l in its elevation spectrum and by its width $\Delta\theta_\pi$, as well as by the width of the power spectrum in the frequency region $\Delta\omega_\pi$. These are described by the corresponding probability density functions $P(l)$, $W(\Delta\theta_\pi)$ and $W(\Delta\omega_\pi)$. The strengths of the separate interference beams that result from various propagation conditions are considered to be independent and are distributed according to exponential law with a mean spectral density N_π in the signal band. The disturbances are considered to be independent, steady Gaussian processes with a zero mean.

The procedure for evaluating the interference immunity of diversity reception is based upon the calculations of the probability of a coincident appearance of concentrated disturbances which simultaneously affect several channels, and upon the calculation of the probability density values corresponding to the spectral density of the interference. It has been shown that the corresponding two-dimensional interference flux also is a Poisson flux with parameters λ_ω, λ_θ, determined by the width of the frequency band $\Delta\omega$, by the width of the directional diagram $\Delta\theta$ of the partial channels and by their relative spacing.

We will examine a reception system possessing m angular channels of diversity spacing, in each of which there are n frequency channels. We will specify: $K[k_{ij}]$ is matrix m x n characterizing the state of the reception channels, in which case $k_{ij}=1$ if in the i angular channel the j frequency channel is affected by interference, and $k_{ij}=0$ if it is not; $\Pi=[\pi_{ij}]$ is matrix m x n designating the interference for which $\pi_{ij}=1$ when channels are simultaneously affected, and for which $\pi_{ij}=0$ when they are not. For example, $\begin{bmatrix} 0 & 1 & 1 \\ 0 & 1 & 1 \end{bmatrix}$ designates an interference aggregate which affect simultaneously the second and third frequency channels in the first and second angular channels of diversity spacing; $x_{[\pi]}$ is the spectral density of the interference in realization $[\pi_{ij}]$.

A certain state of the channels $[k_{ij}]$ in the reception system can be represented by various combinations of simultaneously existing interference which led to that state.

For example, the state of the system $\begin{bmatrix} 1 & 1 \\ 0 & 0 \end{bmatrix}$ is represented by the combinations of interference

$$\left\{\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}, \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}\right\}; \left\{\begin{bmatrix} 1 & 1 \\ 0 & 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}\right\}; \left\{\begin{bmatrix} 1 & 1 \\ 0 & 0 \end{bmatrix}, \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}\right\},$$

possessing various probabilities of occurence.

At the same time, the probability of error is

$$P_{ER} = \sum_t P(\{\Pi\}_t) P_{ER\,K,t}, \tag{1}$$

where

$$P_{ER\,K,t} = \int_0^\infty \cdots \int_0^\infty P_{ER}\left(\frac{E_{ij}}{N_0 + x_{ij}}\right) W(x_{ij})\, dx_{ij} \tag{2}$$

is the partial probability of error determined by combining the diversity signals under the influence in the channel of the t aggregate of interference $\{\Pi\}_t$ which leads to a channel state $[k_{ij}]$; $W(x_{ij})$ is the combined spectral density distribution of the interference aggregate $\{\Pi\}_t$ acting in the ij diversity channels; E_{ij} is the energy of the signal in the ij diversity channel and $P(\{\Pi\}_t)$ is the realization probability of the t interference aggregate.

The spectral density x_{ij} of the interference acting in the ij diversity channel is the sum of the spectral densities of disturbances acting in a given combination and entering the channel.

For example, in the interference aggregate $\left\{\begin{bmatrix}1 & 1\\ 0 & 0\end{bmatrix}, \begin{bmatrix}1 & 0\\ 0 & 0\end{bmatrix}\right\}$ the spectral density in the first frequency channel of the first angular channel is $x_{11} = x_{\left[\begin{smallmatrix}11\\00\end{smallmatrix}\right]} + x_{\left[\begin{smallmatrix}10\\00\end{smallmatrix}\right]}$, and $x_{11} = x_{\left[\begin{smallmatrix}11\\00\end{smallmatrix}\right]}$ in the second.

Taking into account that which has been stated above and assuming that the spectral densities in the combinations are independent, one may write the partial probability of error (2) in the form

$$P_{ER\ K.t} = \int_0^\infty \cdots \int_0^\infty P_{ER}\left(\frac{E_{ij}}{N_0 + \sum x_{[\pi]}}\right) \Pi W(x_{[\pi]}) dx_{[\pi]}, \quad (3)$$

where $\Sigma x_{[\pi]}$ is the sum of the spectral densities of the interference which enters the ij channel.

The probability density function $W(x_{[\pi]})$ can be determined in accordance with [1], where it is shown that

$$W(x) = K_n\left\{\delta(x) + \left[\sum_{l=1}^{L} C_l^{(1)} \frac{x^{l-1}}{N_n^{l-1}} + \sum_{l=1}^{L} C_l^{(2)} \frac{x^{2l-1}}{N_n^{2l-1}}\right] e^{-\frac{x}{N_n}}\right\}; \quad (4)$$

here

$$K_n = \frac{1}{1 + \gamma\lambda_\omega + \frac{\gamma(\gamma+1)\lambda_\omega^2}{2}}; \qquad C_l^{(1)} = \frac{\lambda_\omega P_l}{N_n (l-1)!};$$

$$C_l^{(2)} = \frac{\gamma(\gamma+1)\lambda_\omega^2 P_l}{2N_n(2l-1)!}; \qquad \gamma = \lambda_\theta e^{-\lambda_\theta};$$

P_l is the probability of realization of l beams in the angular interference spectrum; λ_ω is the parameter characterizing the distribution of the interference simultaneously affecting two adjacent channels in the frequency region, spaced at Ω_ω and, in turn, removed from the rest of the channels (not affected by interference) at intervals Ω_1 and Ω_2:

$$\lambda_\omega = \beta \int_0^{\Delta\omega+\Omega_1} \int_{\Omega_1}^{\Omega_\omega+\omega+\Delta\omega+\Omega_1} W(\Delta\omega_n)\, d\Delta\omega_n\, d\omega. \quad (5)$$

Similarly, for elevation diversity spacing

$$\lambda_\theta = \alpha \int_0^{\Delta\theta+\theta_1} \int_{\Omega_\theta}^{\Omega_\theta+\theta+\Delta\theta+\theta_1} W(\Delta\theta_n)\, d\Delta\theta_n\, d\theta. \quad (6)$$

The sum in (1) is obtained according to the possible combinations of interference, that is, $P(\{\Pi\})=1$. The probabilities for the appearance of interference combinations are determined by the probabilities of the interference combinations entering or not entering the corresponding diversity channels

$$P(\{\Pi\}_t) = \Pi P_{\Pi,t} \cdot \Pi P_{\text{н},>t<}. \qquad (7)$$

where the probability of the incidence of combined interference appearing in the t combination[1] is

$$P_{\text{п},t} = 1 - e^{-\lambda_\theta (1-e^{-\lambda_\omega})}; \qquad (8)$$

$P_{\text{н},>t<} = 1 - P_{\text{п},>t<}$ is the probability of non-incidence of all interference aggregates not part of the t combination.

Having employed the general procedure just cited, we will evaluate the interference immunity of dual frequency spaced reception of orthogonal signals with coherent interference of the channel signals under conditions in which single-beam reception is achieved (reception on a pencil-beam antenna or at a frequency close to the MUF). Assuming that the fading is Rayleigh scattering and that it is fully correlated[1], we get

$$P_{\text{ER}} = \sum P(\{\Pi\}_t) \iiint_0^\infty \frac{1}{2 + \frac{E}{N_0 + x_{11}} + \frac{E}{N_0 + x_{12}}} \times$$
$$\times W(x_{[1\,0]}) W(x_{[0\,1]}) W(x_{[1\,1]})\, dx_{[1\,0]} dx_{[0\,1]} dx_{[1\,1]}. \qquad (9)$$

In the case in question the following interference combinations are possible

$$\{[1\,0]\};\ \{[0\,1]\};\ \{[1\,1]\};\ \{[1\,0],\ [0\,1]\};\ \{[1\,0],\ [1\,1]\}\ \{[0\,1],\ [11]\};\ \{[1\,0],\ [0\,1],\ [1\,1]\};\ \{[0\,0]\},$$

possessing the appearance probabilities

$$P(\{[1\,0]\}) = P(\{[0\,1]\}) = P_{\text{п}[1\,0]} P_{\text{н},[0\,1]} P_{\text{н},[1\,1]},$$
$$P(\{[1\,1]\}) = P_{\text{п},[1\,1]} P^2_{\text{н},[01]};\quad P(\{[1\,0],\ [0\,1]\}) = P^2_{\text{п},[10]} P_{\text{н},[11]};$$
$$P(\{[1\,0],\ [1\,1]\}) = P(\{[0\,1],\ [1\,1]\}) = P_{\text{п},[0\,1]} P_{\text{п},[1\,1]} P_{\text{н},[1\,0]};$$
$$P(\{[1\,0],[0\,1],[11]\}) = P_{\text{п},[0\,1]} P_{\text{п},[1\,0]} P_{\text{п},[1\,1]};\quad P(\{[0\,0]\}) = P_{\text{н},[1\,0]} P_{\text{н},[0\,1]} P_{\text{н},[1\,1]}. \qquad (10)$$

The probability of appearance for each interference aggregate comprising the indicated combinations can be determined by (8) where, in accordance with (5)

$$\lambda_{\rho,[1\,0]} = \lambda_{\omega,[0\,1]} = \beta \left[\Delta\omega + \int_0^{\Omega_\omega - \Delta\omega} d\omega \int_\omega^\infty W(\Delta\omega_\text{п})\, d\Delta\omega_\text{п} \right], \qquad (11)$$

$$\lambda_{\omega,[1\,1]} = \beta \int_0^{\infty} d\omega \int_{\Omega_{\omega} - \Delta\omega + \omega}^{\infty} W(\Delta\omega_{\pi})\, d\Delta\omega_{\pi}. \qquad (12)$$

Experimental studies [2] allow us to calculate that $W(\Delta\omega_{\pi})$ can be approximated in the following manner:

$$W(\Delta\omega_{\pi}) = 0{,}95\, e^{-2{,}5\Delta\omega_{\pi}} + 0{,}25\, e^{-0{,}4\Delta\omega_{\pi}}. \qquad (13)$$

The partial probability of error with one affected channel is equal to

$$P_{ER,[01]} = P_{ER,[10]} = \int_0^{\infty} \frac{1}{2 + \frac{E}{N_0} + \frac{E}{N_0 + x}} W(x)\, dx -$$

$$- \frac{1}{h^2 + 2} \Bigg\{ 1 - \frac{1}{\gamma\lambda_{\omega} + \frac{\gamma(\gamma+1)\lambda_{\omega}^2}{2}} \Bigg[-\gamma\lambda_{\omega} \frac{h^2}{(h^2+2)\xi} e^{\frac{h^2}{(h^2+2)\xi}} E_l \times$$

$$\times \left(-\frac{h^2}{(h^2+2)\xi} \right) + \frac{\gamma(\gamma+1)\lambda_{\omega}^2 P_l}{2(h^2+2)\xi} \Bigg] + \frac{\gamma(\gamma+1)\lambda_{\omega}^2}{2} \Bigg[\frac{h^2}{(h^2+2)\xi} \times$$

$$\times E_l \left(-\frac{h^2}{(h^2+2)\xi} \right) e^{\frac{h^2}{(h^2+2)\xi}} \Bigg] \Bigg\}. \qquad (14)$$

In (14) W(x) is obtained from the general formula (4) when

$$P_1 = 1;\ l = 1;\ \xi = \frac{N_0}{N_0}$$

and

$$h^2 = \frac{E}{N_0}, \qquad E_l(x)$$

is the integral exponential function.[3]

In calculating the partial probability of error with two affected channels $P_{ER[11]}$ the integral is not computed in its final form, since we will evaluate it from above and from below. We will obtain the upper evaluation if we consider the spectral densities of the interference in the channels to be fully correlated and identified. Distribution (4) has the parameter $\lambda_{\omega\pi}$ corresponding to the maximum value of the parameter for all q interference aggregates, while parameter $\lambda_{\theta} = \sum_q \lambda_{\theta,\pi}$ (in the example being considered λ_{θ}=const., since reception with respect to the angle is single-channel). Considering the spectral densities of interference in the channels to be independent and assuming that the distribution of the spectral density of interference in each channel affected by interference corresponds to the distribution of the smallest spectral density of interference in all the affected channels, we get an evaluation of the partial probability from below. Calculations show that the evaluations from above and below are equal to, respectively:

$$\bar{P}_{ER\,(1,1)} = \int_0^\infty \frac{1}{2 + \frac{E}{N_0 + x}} W(x)\,dx = \frac{1}{2}\left\{1 - \frac{1}{\gamma\lambda_\omega + \frac{\gamma(\gamma+1)\lambda_\omega^2}{2}} \times \right.$$

$$\times \left[-\gamma\lambda_\omega - \frac{h^2}{\xi} E_i\left(-\frac{h^2}{\xi}\right) e^{\frac{h^2}{\xi}} + \frac{\gamma(\gamma+1)\lambda_\omega^2 h^2}{2\xi}\right] +$$

$$+ \frac{\gamma(\gamma+1)\lambda_\omega^2}{2} \left(\frac{h^2}{\xi}\right) E_i\left(-\frac{h^2}{\xi}\right) e^{\frac{h^2}{\xi}}; \qquad (15)$$

$$P_{ER\,(1,1)} = \int_0^\infty \frac{1}{2 + \frac{2E}{N_0 + x}} W_{MIN}(x)\,dx = \frac{1}{2} - \frac{1}{2}\left\{e^{\frac{2h^2}{\xi}} E_i\left(-\frac{2h^2}{\xi}\right) \times \right.$$

$$\times \left[(d_1 + d_2 - 2)\frac{2h^2}{\xi} + 2(d_1 + d_2 - d_1 d_2)\left(\frac{2h^2}{\xi}\right)^2 - 2d_1 d_2 \left(\frac{2h^2}{\xi}\right)^3\right]\right\} -$$

$$-(d_1 + d_2)\frac{2h^2}{\xi} + d_1 d_2 \left(\frac{2h^2}{\xi}\right)^2, \qquad (16)$$

where $d_i = \dfrac{\lambda_{\omega i}(\gamma_i + 1)}{2 + \lambda_{\omega i}(\gamma_i + 1)}$.

Having calculated the probabilities of appearance of interference combinations according to (10) and with consideration given to (11)-(13), and having evaluated the partial probabilities of error with the help of (14)-(16), we obtain an evaluation of the composite probability of error according to (1).

In figures 1, 2, and 3 we have cited the results of an evaluation of interference immunity for various frequency shifts between the channels with a passband $\Delta\omega$=0.5 kHz where $\overline{\Delta\omega_\pi}$=1.6 kHz (curve 1 corresponds to single reception; 2 is dual reception with Ω_ω=0.5 kHz; 3 is dual with Ω_ω=1 kHz; 4 is dual with Ω_ω=2 kHz; 5 is dual reception in the assumption $\Omega_\omega \to \infty$). The solid line in fig. 1 corresponds to the evaluation from above, while the dotted line is the evaluation from below (in view of the slight difference between the evaluations, only the evaluation from below will be shown in the following figures).

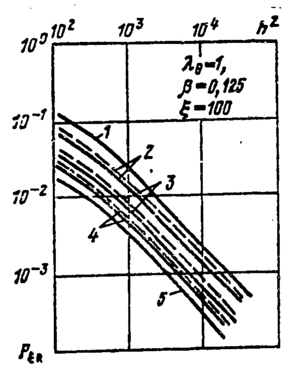

Fig. 1

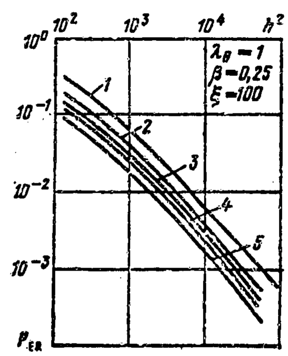

Fig. 2

The results obtained allow us to judge the effect of the intensity of interference with respect to frequency and angle and to judge the effect of the frequency separation of the channels on the interference immunity of frequency diversity-spaced reception. From an analysis of the curves in figures 1 and 3 it follows that, with a value of Ω_ω=2 kHz for the separation between the frequency channels in channels having the same average intensity of interference $\lambda_\theta \lambda_\omega$, the transition from a channel having an interference intensity of λ_θ=1 with respect to the angle and β=0.125 with respect to frequency to a channel possessing λ_θ=0.5 and β=0.25 leads to an energy loss of 1 dB in comparison with the case of frequency channel separations $\Omega_\omega \to \infty$ at the level P_{ER} =10^{-3}. From figures 2 and 3 it is obvious that an increase in the channel loading (with respect to the angle) from λ_θ=0.5 to λ_θ=1 leads to the energy gain at the P_{ER} =10^{-3} level being reduced from 7.5 to 4 dB in the case of a transition from single to dual reception with a frequency separation of the channels Ω_ω=2 kHz.

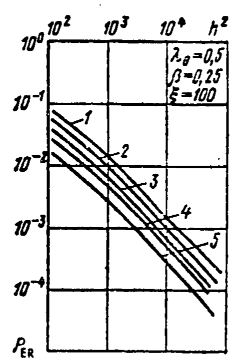

Fig. 3

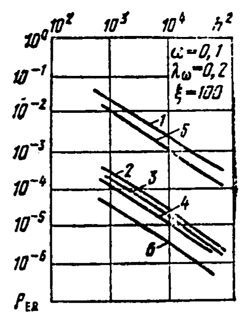

Fig. 4

Having employed the suggested technique, we will examine the dual elevation diversity-spaced noncoherent reception over a 3000 km route during daytime summer operation at an optimum working frequency 85 percent of the MUF. The partial directional diagrams of the antennas for the diversity spacing channels have a width of $\Delta\theta$=5° and an elevation of the antenna directional diagram θ_1=18°, θ_2=23° in the first case and θ_1=18°, θ_2=28° in the second, that is, the partial directional diagrams used have an elevation diversity spacing of the central angles equal to Ω_θ=5° and Ω_θ=10°. Such positioning of the partial directional diagrams is characteristic when a Batler-type matrix is employed as the diagram-generating scheme.[4]

The fading of the signals in the channels is Rayleigh scattering and independent. The strength of the interference in the channels is likewise assumed to be independent in the hypothesis of the independence of the individual beams' strengths.

As the Smith-method calculation of the signals' energy spectra shows, in the case of the assumption that the interfering stations are evenly distributed on the surface of the earth, one may with some degree of approximation consider the assessment of the width of the interference energy spectrum for the given conditions of communications to be normal, with parameters of $\overline{\Delta\theta_\pi}=15°$ and $\sigma_{\Delta\theta_\pi}=5°$.

The distribution of the number of interference beams entering into a directional diagram of width $\Delta\theta$ is equal in this case to

$$P(l) = 0{,}3\delta(l-1) + 0{,}4\delta(l-2) + 0{,}15\delta(l-3) + 0{,}15\delta(l-4).$$

Having calculated the parameters of distributions x for various interference combinations, we obtain values for the total probability of error.

In figure 4 we have cited the results of calculations for the probability of error with elevation diversity-spaced reception (curve 1 corresponds to single reception; curve 2 is dual reception with $\Omega_\omega=5°$; curve 3 is dual reception with $\Omega_\omega=10°$; curve 4 is dual reception in the assumption $\Omega_\theta\to\infty$). Curves 5 and 6 correspond, respectively, to single and dual reception in the assumption that the width of the interference spectrum is considerably less than the elevation width of the directional diagram of the diversity channel antennas. As we see, the magnitude of the angular separation is not of substantial importance for the interference immunity. This can be explained by the considerable width of the interference spectrum under the given conditions of communication. At the same time, the width of the elevation spectrum of the interference has a substantial influence upon the interference immunity of diversity reception. For example, the energy gain in interference immunity with the introduction of elevation diversity spacing in the case of an interference spectrum of narrow width (figures 5 and 6) is 3.5 dB greater than in the case of interference possessing a comparatively wider elevation spectrum (figures 1 and 4).

Although the cases under examination have their independent value, they do possess a peculiar character. For a concrete communication route and method of reception using the technique suggested, it will be necessary to conduct a detailed analysis with consideration given to the peculiar nature of the signal's elevation spectrum and to select the optimum parameters for the communications system.

BIBLIOGRAPHY

1. Belov, P. V. and Orlov, V. I. RADIOTEKHNIKA, Vol 33, No 3, 1978.

2. Komarovich, V. S. and Sosunov, V. N. "Sluchaynyye radiopomekhi i nadezhnost' KV svyazi" [Random Radio Interference and the Reliability of SW Communications], Moscow, Svyaz', 1977.

3. Gradshteyn, I. S. and Ryzhik, I. M. "Tablitsy integralov, summ, ryadov i proizvedeniy" [Tables of Integrals, Sums, Series and Products], GIFML, 1963.

4. "Antennyye reshetki" [Antenna Grids], Moscow, Sovetskoye radio, 1966.

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ELECTRONIC FILTERING SYSTEMS EMPLOYING RECURRENT HETERODYNING

Moscow RADIOTEKHNICHESKIYE SISTEMY FILTRATSII S VOZVRATNYM GETERODINIROVANIYEM in Russian 1979 signed to press 11 Mar 79 pp 2, 269-270

/Annotation and Table of Contents from the book by Viktor Aronovich Levin and Gennadiy Alekseyevich Norkin, 4,800 copies, 272 pages/

/Text/ Examined herein are the theory and methods of the design of electronic filtering systems employing recurrent heterodyning(SFG), which are receiving wide-spread application in multiband transceiving equipment and frequency stabilization systems, in particular, in synthesizers and other such uses.

The presentation of the material is based on an analysis of the basic block-elements of SFG, and on a study of the system as a whole. Examples of engineering designs of SFG are discussed. The use of different versions of SFG in electronic equipment is considered.

The book is intended for specialists in the field of radiocommunication, radionavigation, and radiomeasurement technology, but may also be used by students in senior-level courses of the electronics departments of higher educational institutes.

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USE OF THE "PENTAKONTA" AUTOMATED TELEPHONE EXCHANGE IN THE URBAN TELEPHONE SYSTEM OF THE USSR

Moscow ELEKTROSVYAZ' in Russian No 1, 1980 pp 53-61

[Article by Yu. I. Yemel'yanov, manuscript received 20 Mar 79]

[Text] It is difficult to exaggerate the import of telephonic hardware in the welfare of a highly developed state. By resolution of the CPSU Central committee and the USSR Council of Ministers, taken in August 1976, measures are foreseen for the accelerated development of urban telephone grids. The chief administration of urban telephone communications of the USSR Ministry of Communications, by taking steps to fulfill government assignments, plans to use the "Pentakonta" automated telephone exchange (ATC) in addition to ATC of domestic design—the RS-1000C produced in Poland on license from France. This station, while not the latest word in communications technology, does represent one of the most prevalent and mature coordinated ATS systems from the viewpoint of production and operation.

Problems of introducing the RS-1000S station in urban telephone grids of our country are considered and a description of the operation of the station and its individual components is given.

General information

The "Pentakonta" system is a coordinated commutation system with register control. It contains an entire gamut of telephone stations of various purpose: international, interurban, urban, rural and institutional. Production of these stations was arranged on the basis of a unified component base and standard design.

For transmission of interregister control signals in the "Pentakonta" system are used battery and dipole multifrequency codes of the type R_2. In addition, it is possible to connect additional devices designed for transmission and reception of a third kind of signal typical of national grids where these stations are employed.

Urban telephone stations of the "Pentakona" system

These were elaborated in the 1950's. Type RS-1000S ATS are one of the latest modifications of the system. The difference between it and other coordinated systems is that transmission of conversational information and control signals takes place along different paths. Control signals are transmitted by signal code along multi-lead information tracts. This assures, on one hand, a "clean" conversational tract, and on the other hand, acceleration of transmission of control signals which, in turn, makes possible the optimum use of the central controls.

The structural diagram of the urban ATS RS-1000S is shown in Figure 1 (in this and other figures, abbreviations corresponding to supplier documentation are used: TR_{in}—input trunkline relay; SR—register seeker; RP—incoming register; SP—auxiliary seeker; ND—level sensor; NR2—multifrequency sensor; DW—seeking connector; CSL—customer step label; CSG—group step label; RA—local register; DP—preselection connection set; P-allotter, etc.). The diagram shows that customers' telephone equipment is included in the customer seek step SL with the aid of a register set ZP are switched through to the group seek step SG where, with the aid of the outgoing trunkline register TR_{out} or intrastation connection power circuit, they are organized either with the coupling junctions or stations, or through the customer step with telephone equipment of customers of the given ATS (intrastation connection).

Establishment of connections is ensured by control devices which will be discussed later.

The RS-1000S ATS mainly uses two-link commutation units. However to improve load service during peak loads (ChNN), in one link are used the so-called mutual assistance lines and connectors which are commutation elements connected to the circuit, when necessary, only to handle the excess load.

Units of the customer and group seek steps are serviced by labels—two for each unit. In design concepts, they are placed togehter with their seek steps, but are functionally contained in the control sets.

Introduction of the type RS-1000S ATS in USSR urban telephone networks involves certain problems caused by the specific design of our urban t^lephone networks (GTS). Thus, before using these ATS in the USSR GTS, it is necessary to remodel the sations. Let us discuss in greater detail the basic differences between the "Pentakonta" system and the communcations system used in our country's GTS.

1. The first and foremost distinction is the use of two different multi-frequency codes for interregister signalling: in the RS-1000S ATS they use battery and double-band multifrequency R_2 codes, while the GTS of our country uses a one-band multifrequency code "pulse chute" R_1-ATSK in addition to the battery code [1]. In practice, this means the stations of the RS-1000S and stations used in the USSR GTS "speak" different languages. "Teaching" the RS-1000S the language used in the USSR GTS is a major problem in adapting the system.

2. We know that urban telephone stations in the USSR have transmitting devices for determining the number of the calling customer—AON which is intended, along with other purposes, to solve the problem of calculations of automatic intercity conversations. In the RS-1000S station they have customer counters whence are transmitted the rate pulses from the AMTS. In the same counter are calculated local conversations, but only their number without consideration of length.

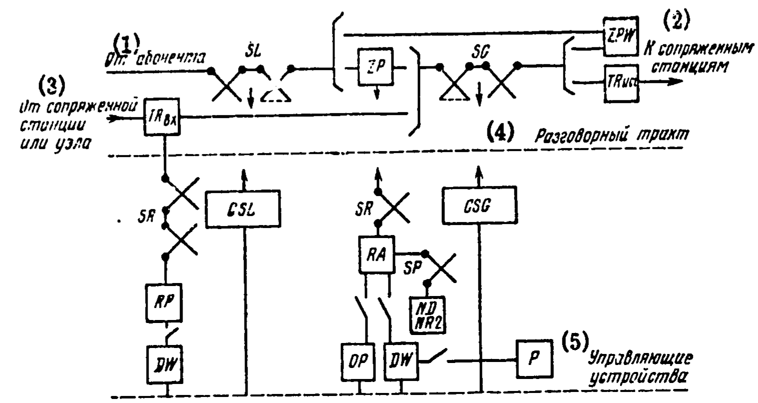

Figure 1

Key: (1) from customer
(2) to coupled stations
(3) from coupled station or junction
(4) conversation tract
(5) control devices

Thus even with time calculation of local telephone calls, the decision on whose introduction was adopted by the USSR Ministry of Communications and in connection with the fact that the ATS RS-1000S will operate in the USSR GTS in the near future, the question has arisen about the introduction of AON equipment into the RS-1000S system.

3. The RS-1000S stations are designed for power supply from the 48 V station battery. In the USSR GTS the power supply is 60 V. The use of two types of electrical power installations (EPU) with the ATs in standard building where areas for EPU are limited presents considerable difficulties, since in the ATS building, as a rule, in addition to the ATs there are commutation junctions and LATs of the transmission systems which need 60 V power supply. Furthermore, this same power rating is required for the trunkline relays which operate with coupled stations and junctions where 60 V is used.

Nevertheless, the USSR Ministry of Communications adopted the decision at least before 1980 inclusively to use the RS-1000S powered by 48 V, since otherwise it will be necessary to expend much labor to redesign all elements of the station to the indicated voltages, which would lead to a delay in station introduction.

4. In the USSR GTS there are various types of lines: physical and multiplexed, analog and digital, incoming, outgoing and interurban, two-lead, three-lead and four-lead and so forth. In order to ensure normal operation of the RS-1000S in the USSR telephone grid, the lines should be matched with the station for which elaboration of special trunkline relays (translators) is required.

5. There are other discrepancies to the RS-1000S system of telephone communications adopted in the USSR GTS: another operating algorithm of the RS-1000S stations with manual intercity stations: tracts are not separated for local and intercity messages; another principle of connection of intercity telephone automatons in the RS-1000S; different composition of line signals than the GTS; different acoustic signals and some other technical issues which must be resolved for the RS-1000S to operate well.

Work on adapting the ATS RS-1000S for normal operation in the USSR GTS was done jointly with Polish and Soviet experts. In 1978, assembly was begun in the USSR on the first propotype ATS with 10,000 numbers, designed for operation in large cities. In 1979 it was put into operation. In this station the basic systems and technical questions hare been resolved which were mentioned earlier, except for elaboration of the entire set of matching devices— translators and the use of the exchange as a junction.

Currently technical conditions for the prototype ATS RS-1000S are being examined for the following type of trunkline relays (translations).

To ensure incoming connections; TVF-4 and TVFM-4 for four-lead physical lines used for the GTS and for operation with AMTS type ARM-20; TVFSh-2 and TVFK-2--for two-lead physical lines from level-step and coordinated AATS and junctions; TVFK-3—for three-lead physical lines from coordinated ATS and junctions; TVShM-3—for three-lead physical lines with connection to the AMTS-2; TVUSh, TVUShM and TVUK—for lines multiplexed by "Kama" equipment from level-step ATS and junctions, intercity junctions and coordinated ATS and junctions, respectively; TVFA-3—for three-lead lines from the UATS-49.

Furthermore, there are trunkline relays (translations) for operation with incoming connective lines formed by IKM-30 equipment: TVISh, TVIShM and TVIK—from step ATS and MTS and coordinated ATS and junctions, respectively.

To ensure outgoing connections. TIF-4—for four-lead lines, TIF-2 and TIF-3 for two-lead and three-lead physical lines; TIFA-3—for three-lead lines connected to UATS-49; TIU and TII—for operation on lines multiplexed by "Kama" equipment and IKM-30, respectively.

RS-1000S Component Base

The basis of the station is made up of a repeat coordinate connector (MKS) of the "Pentakonta" type, which differs from other types of MKS in the larger number of horizontals and verticals. The standard MKS has 14 horizontals and from 8 to 22 verticals. Each vertical contains 28 contact groups with 6, 8, 9 or 10 contact springs each. The MKS provides connection from 8 to 22 inputs with 28 outputs with six-, eight-, nine- and ten-lead commutation. According to the conduction of commutation, it is possibile to get 52 four-lead or 74 three-lead outputs.

In contrast to MKS of other systems, the "Pentakonta" connector uses a universal assembly frame, part of which is occupied by the relays, which are MKS equipment. The "Pentakonta" MKS weighs about 80 kilograms and is installed with a special hoist.

Control and other devices of the ATS are built on standard "Pentakonta" relays: relays with round coils; relays with oval coil and repeat relays. Relays with round coils are used when it is impossible to use relays with an oval coil, e.g. with low power requirements, if necessary to retard cycling. In all other cases relays with oval coils are used, including assembly of a repeat relay. Relays with oval coils are assembled two per housing, just as for a single coil with a round coil, which makes the equipment more compact.

Repeat relays are assembled from 20 relays with oval coil in a common housing with common repeat field. These relays are used in arranging information tracts between interactive control devices.

Contact springs of the relays are assembled into contact groups of 32 or 33 springs each (another arrangement is possible) which ensure making, breaking and switching of contacts, including switching without circuit loss.

The station also uses electronics components: transistors, SCRs, diodes etc. The AON equipment is designed on ICs.

Commutation and control devices of the RS-1000S ATS

The following are related to commutation devices of the ATS: customer seek step units; GI step units of register and auxiliary seek devices for connection of registers, sensors, code reception transmitters, counters, etc.

ATS control devices are divided into devices designed to control establishment of a connection and for exchange of control signals--information tracts. The first includes labels, registers, counters, connectors, sensors and code receivers. The information tracts contain connectors of rate circuits and code sensors and connectors forming a tract for information exchange between control devices.

The basic commutation and control devices in the RS-1000S ATS are the same as in any other coordinated system and do not require any detailed investigation. Some more details should be given on counters and information tracts.

The allotter decodes number dialing signals stored in the registers and uses them to control the connection and in determining payment for the call. The allotter records the customer category and connection type in its equipment, which makes it possible to introduce certain constraints or priorities on telephone conversations.

As was said above, in the RS-1000S system, the ATs uses allotters to calculate telephone calls and their payment. This is the per-call payment system, i.e., payment for a specific (constant) tariff for the number of calls without regard of their length. With introduction into the USSR GTS of a proposed time system of call computation, the function of the call payment alloter will not be used or will be used in the prototype ATS for experimental purposes. Henceforth it will be necessary to alter the allotter circuit in the payment section for local calls on the basis of their length, in three-minute multiples.

A basic part of the allotter is the decoding field for translation of signals received in MFC code into signals necessary to control the connection.
The allotter interreacts only with the registers; it is designed in the form of a discrete element so that it can be connected to a larger number of registers because of its short time of operation with each of them.

The information tracts are used to transmit information from one control device to another. The throughput of the tracts reaches 66,000 operations per hour. Channels of the information tract consist of repeat 20-armature relays. Each armature has 11 making contacts attached to it. The stationary springs of these 11 contacts form a repeat field. To obtain the 20-lead commutation used in information tracts, two repeater relays must be connected to each channel.

In high capacity ATS, special information tracts of each channels each are used to increase throughput.

Structural Diagram of the RS-1000S

According to customer category and their load, three types of customer seek units can be used: for low, moderate and high traffic, characterized by the following loads: 0.067-0.08, 0.1-0.117 and 0.133-0.15 Erl/customer; this must be considered when the station is planned. The maximum capacity of the ATs in this instance ranges from 40 to 27,000 numbers.

To include customer telephones creating a very high load on one line in the station, or to connect large institutional stations into the RS-1000S, special one-link units with load capacity of 0.456 and 0.760 Erl/line are provided. The use of station current depends on the serviced load and in the RS-1000S constitutes 0.8-1 A/Erl, i.e., in practice, a 10,000 ATS needs 1000-1500 amperes EPU. The structural arrangement of the RS-1000S station adopted for operation in the Moscow GTS is shown in Figure 2.

The customer unit of the station (ESL) is designed to include 1000 customers. The type T6 seek customer step unit has 1,036 outputs, 1000 of which are used to connect customers and are considered in the numeration; the remaining 36 may be used only for outgoing traffic, e.g., to connect automatic telephones or to connect small institutional ATS for outgoing connections. To service outgoing loads from the 1,000 customer UATS-49, a unit of slightly higher throughput is used, the type T8.

The incoming load to an institutional station is transmitted from the group seek step.

The outgoing load from the RS-1000 is serviced by outgoing group seek units forming the outgoing group seek step, which consists of three parts of two units each with labels in each: ESGD0 through ESGD5. Each group seek unit has 1,040 outputs (units with 2,080 outputs can be used also).

ESGD are attached to every other unit: 60 outgoing registers (ED), two allotters (T), one allotter connecting set (CT), 12 seek connecting sets (CS), 12 preselection connectors (CP), nine multiple frequency transmitters of type R_1-ATCK (ENVM), 18 battery code trasnmitters (ENVS), one auxiliary seek unit for connection of registers to code sensors (LA), nine register seekers (CE), 360 (26 for each seeker) register sets (JE).

The function of the register sets is to form a connective path between the caller and the register ED, and also to etablish an information tract between this register and the input of the group unit. After preparing the connection, the sets ensure connection through of the output of the customer unit "straight" to the input of the group unit.

The circuit of the output step of the group seek is constructed so each unit has access to a common bundle of 1,040 outputs. The outputs are divided in the direction of the external communications and intrastation connections and end in translators whose types are cited above. There are also outputs to the autoinformer.

It is necessary to note that the intrastation load from the group seek step to the customer seek step is transmitted along two paths: directly and in a circuitous route to inputs of the incoming group seek step ESGA and across it--to the cutsomer step. Because of this, the minimum of rejections is achieved for intrastation communication with a minimum of expenditures.

To service the incoming load in the RS-1000S, there is an ear-marked incoming group seek which consists of six group units ESGA0 through ESGA5. This seek step is serviced by control devices: incoming registers EAM and EAS for incoming communication from coordinate and level-step systems, respectively; auxiliary seekers LA; seek connectors CS to assure access to the information tract of the incoming load FCESGA.

Passage of the transient load occurs as follows. Incoming information about the station number is recorded in the EAM or EAS registers; this information passes through the seeker LA and enters the code transmitter ENVM or ENVS and is fed out to the outgoing register ED. The further connection is like an outgoing communication.

As was noted above, in the "Pentakonta" system, control signals and conversational information are isolated, i.e., different paths of transmission are used. In the prototype RS-1000S ATS, for transmission of control signals there are four information tracts: preselection, group seek, line seek and incoming messages. Each information tract has four channels, through each of which simultaneously is transmitted several kinds of information.

In the skeletal circuit, a simple representation is given of AON equipment which completely meets USSR GTS requirements; therefore its purpose and description of operation will not be given here.

Principles of Establishment of Connections in the RS-1000S ATS

The process of establishing connections may be divided into several phases: preselection, group seek, number dialing, line seek, establishment of conversational circuit.

In the preselection phase, the line of the calling customer is connected to one of the free registers and information is also transmitted on the category of caller from the label to the incoming register. The phase ends when the caller's line (customer A) is connected to the register. The dial tone comes from the register and the customer may dial the number. All auxiliary control devices except the register are freed.

The number dialing phase begins after the dial tone and ends with recording of the complete call recipient's number (customer B) in the register.

The group seek phase begins simultaneously with the number dialing, but connections begin only after the register perceives a specific number of digits (three or seven) by which it determines the necessary direction (direction code). After this, the register with or without the allotter (according to the type of coupled station) transmits information to the group unit label with the aid of the information tract FCESGD.

Then the regular work takes place for coordinated ATS and the group seek phase terminates with the establishment of a connection from the customer unit through the group unit of the outgoing step to the corresponding connective line set (then through the grid) or to the output of the customer unit which includes customer B (with intrastation communications).

In the latter case, the line seek phase begins immediately. By this time, the register has locked in all the number digits of customer B and uses the last three digits which are transmitted to the label along the line seek tract FCESLDe to determine the category and number of the customer unit output to which customer B is connected and makes a test of his line.

The test results of customer B's line and data on his category are transmitted across the information tract FCESGD to the register. If the customer is free, the connection seek set establishes a conenction through the customer unit. All control instruments are freed. The established connection is maintained by the

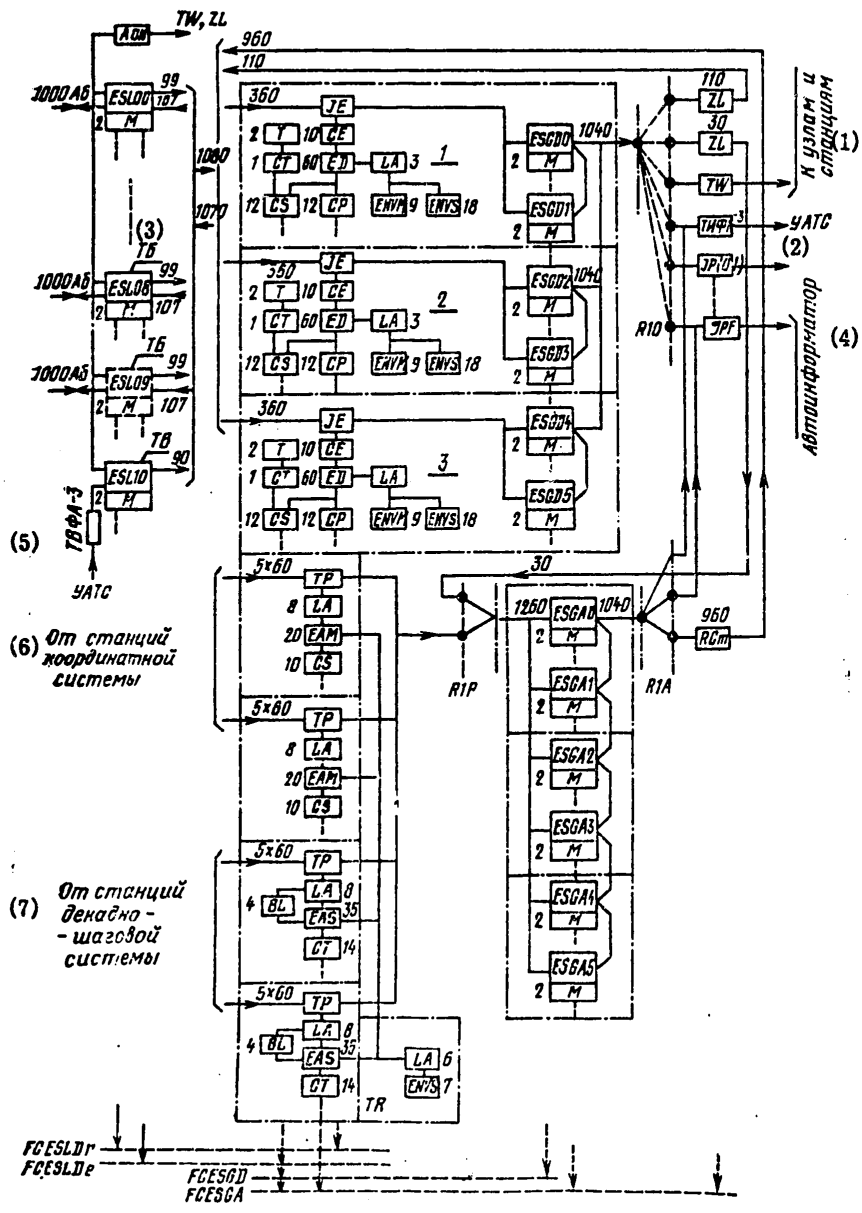

Figure 2

Key:
(1) to junctions and stations
(2) UATS
(3) TB
(4) autoinformer
(5) TVFA-3
(6) from stations of coordinated system
(7) from stations of level-step system

local connective set ZL.

If customer B is busy, information about this is transmitted to the register through the same information tract, after which by instruction of the register the established connection is broken and all control devices are freed. Customer A receives a busy signal from his telephone set.

Establishment of outgoing connections and incoming connections occurs similarly, except that instead of the customer line, the incoming or outgoing connection line set (translator) is connected to the register; on the basis of the direction category (which is defined by the label and register), the register determines the kind of connection and analyzes which code is required to further transmit information on the number of customer B. According to the results of analysis, the register connects to itself the appropriate code transmitter using the auxiliary seeker LA and a signal is sent toward the coupled junction or station on the customer's number either in code R_1-ATSK (to coordinate junctions and ATS) or in battery code (to step junctions and ATS), from the transmitters ENVM and ENVS, respectively. After establishment, the connection is maintained using the outgoing line set (translator). It powers the microphone and calculates the call after the called customer answers.

Electrical Parameters of Customer and Connective Lines

The RS-1000S ATS operates stably with the following electrical line parameters:

Customer lines: loop resistance no more than 1,300 ohms (without telephone equipment) or no more than 1,600 ohms (with telephone equipment); insulation resistance between leads and between leads and ground--at least 20,000 ohms; permissible line capacitance without telephone hardware--no more than 0.5 microfarads; maximum combination of line parameters at which normal operation of pulsed circuits is possible: R = 1,300 ohm, C = 0.5 microfarad, R_{ut} = infinity; R = 0, C = 0, R_{ut} = 20,000 ohms.

In conformity with requirements imposed on the USSR GTS, the RS-1000S stataion must ensure operation on lines of remote customers included in special sets. The following parameters of these lines should be observed: loop resistance no more than 3,500 ohms (without telephone set); insulation resistance between leads and between the lead and ground--at least 30,000 ohms; permissible capacitance between leads or each lead and ground, no more than 1 microfarad; maximum combinations of line parameters at which normal operartion of pulsed ciruicts should be assured: R = 3,000 ohm, C = 1.0 microfarad, R_{ut} = infinity; R = 0, C = 0, R_{ut} = 30,000 ohms.

Connective lines: Physical two- and three-wire lines. Resistance of each conversational conductor is no more than 700 ohm; with trunkline relay set, no more than 1,500 ohm; resistance of the third wire without the trunkline relay set, no more than 1,500 ohm; insulation resistance between line wires or between each lead and ground--at least 150,000 ohms; permissible capacitance between leads--no more than 1.6 microfarad; normal operation of pulsed circuits occurs with the following maximum combination of parameters: R = 3,000 ohm, C = 1.6

microfarad, R_{ut} = infinity; R = 0, C = 0, R_{ut} = 150,000 ohms.

Physical connective lines in communications with interurban stations (two and three wire lines are used): resistance of each conversational lead no more than 1,000 ohms; insulation resistance betweeen wires or the wire and ground at least 150,000 ohms; permissible capacitance between line conductors no more than 1.3 microfarads; resistance of third wire is similar to line parameeers for the GTS; proper reception of d.c. pulses occurs with the following maximum combination of loop parameters: R = 2,000 ohms, C = 1.3 microfarad, R_{ut} = infinity; R = 0, C = 0, R_{ut} = 150,000 ohms.

Design of the RS-1000S ATS

The basic design unit of the station is the frame (Figure 3) in which the MKS, relays, IDF boxes and other equipment are placed.

Equipment is delivered to the facility in frames and they are assembled using assembly fittings and extruded aluminum structures into bays and are set in rows. The concept of "bay" is arbitrary, since it is not produced in the plant (as compared, let us say, with the domestic ATSK), but is assembled right at the facility for the frame width to be used.

The frame skeleton is made in the form of a rigid steel welded construction. All internal equipment of the frame is attached to the horizontal cleats: MKS, relay plates, boxes, etc. Its dimensions are 1,290 x 390 x 200 millimeters. This is a standard frame, but frames of other type sizes may also be used.

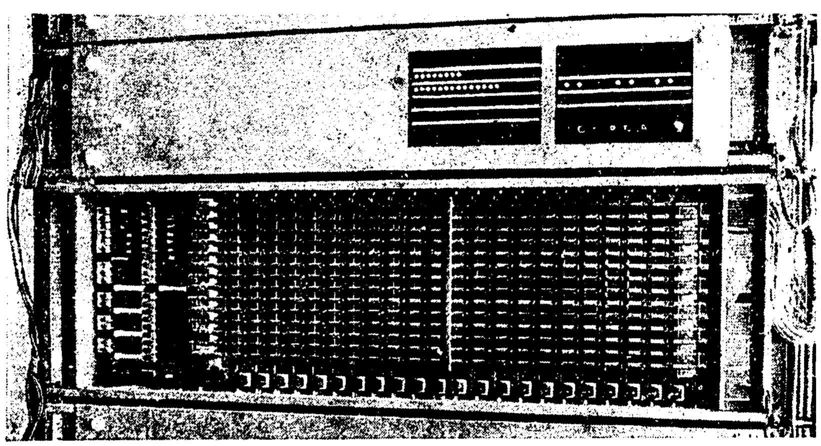

Figure 3

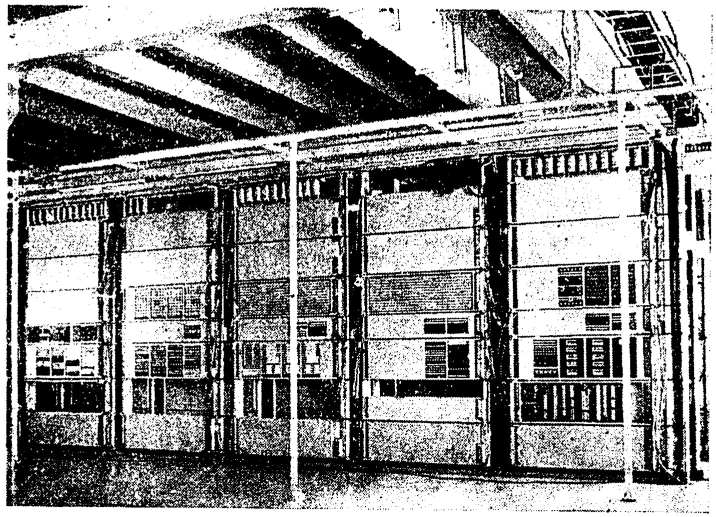

Figure 4

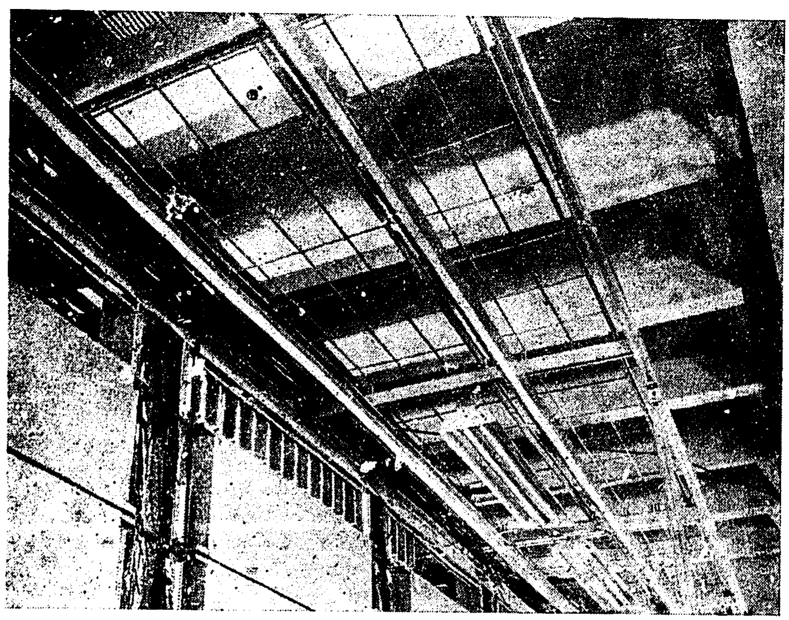

Figure 5

As was already noted, the frames are attached in bays. The bays consist of vertical columns which are attached on top and on bottom to connective cleats common to the row. The spaces formed in column installation (between the column of one bay and the column of its neighbor under the cover of the connecti cleats, etc.) are used for laying the cables of interbay assembly and power cables.

The height of the bays used depends on the height of the rooms designed for installation of the RS-1000S. Standard bay heights have been adopted: 2270, 2670, 3070 and 3470 millimeters. For standard ATS buildings in USSR cities, the typesize of 3040 was adopted. But if necessary, equipment of another height dimension may be ordered. The width of the bay is defined by the width of the frame. It may be 725 or 1450 millimeters.

According to the height of the bay, it holds from five to eight (without power frame) or from four to seven (with power frame) frames.

The bays have a monitoring panel. A typical difference between ATS of the "Pentakonta" system is that in each bay there is an IFD frame, and "lattice" type metal structures are used as the cable tracks, making it possible to lay station cables along the shortest paths. This saves station cable.

Figures 4 and 4 show bays asembled in rows during the assembly process in the automatic switch room, and some of the the "lattice" type metal structures.

Assembly of ATS is mainly carried out by the screw-on method, using special screw ratchet tools. Many standard connections (e.g., connections inside the bays and between them) are done by the flexible cable method with multicontact plug connectors which must be connected at the plant.

Various areas are required for placement of the RS-1000S according to the height of the bays. Thus, for a 10,000 number station, the bay height of which is 3470 millimeters, an area of about 400 square meters is required; where bay height is 3070, 500 square meters are required; for lower heights, about 100 square meters more are required.

The load capacity of automatic switching hall roofs should be at least 650 kg/square meter.

Operation of RS-1000S ATS

The station is intended for operation by the monitoring-correction method. The essence of the method is familiar: the quality of communications is monitored by comparing it with a desired "threshold"; on-line intervention by service personnel is only done if the permissible level is exceeded ("threshold") in communications quality. Preventive work is mainly envisaged only to test the working order of the monitoring-testing equipment and signal devices; this necessitated providing the station with the necessary technical hardware for observation and monitoring of ATS operation and communications quality.

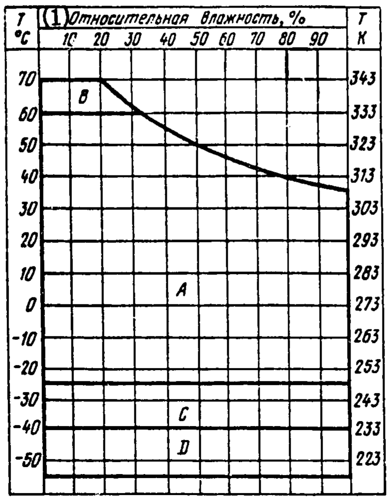

Figure 6
(1) relative humidity, percent

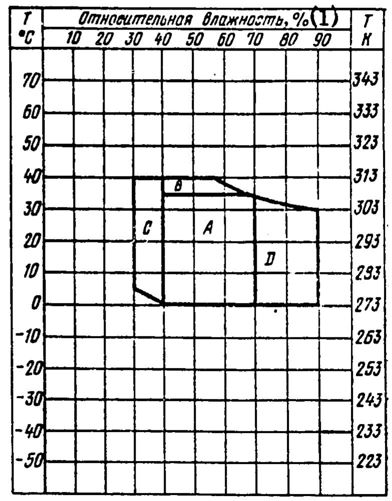

Figure 7
(1) relative humidity, percent

Technical operations hardware includes all devices making it possible to evaluate station operation quality, to establish the kind of damage and its location. In particular, panels, bells and so forth for feeding alarm signals; rejection counters for statistical evaluation of communications quality; erlangometers for monitoring and measuring load; device for detecting and recording damage via teletype; automatons for generating outgoing and incoming messages to control outgoing connection lines; automatic robot for generation of 10 simultaneous messages; devices for monitoring passage of incoming and outgoing messages via predetermined devices: labels, registers, connecting sets, allotters, etc.; test table for testing customer and connective lines; device for testing customer incoming registers; device for testing allotters.

All these instruments and devices (except for devices for testing registers) are made in standard frames and are built into the bay. The set of technical service hardware can include another two key pulsers and up to ten sets of anonymous call tracers.

Conditions for Transporting and Storing Equipment. Working Conditions of the Environment

Figures 6 and 7 show the permissible conditions of temperature and humidity for transporting, storing and operation of ATS. The thick line in the figures bounds the zone of possible s tion content. The temporary limitations of equipment in these zones are: Figure 6—zone A—maximum of 6 months; zone B—maximum of 24 hours; zone C—maximum of three months; zone D—in aircraft, maximum of 16 hours; Figure 7 (normal operating conditions)— zone A—minimum of 36 years; zone B—maximum of four years; zone C and D—maximum of 1% of service life of station with arbitrary distribution.

References

1. Kutashov, P.D. et al. Gorodskiye koordinatnyye ATS tipa ATSK [Urban coordinated automated telephone exchanges of the ATSK type], Moscow: Svyaz', 1970.

3. Shchepanski, Ye. Uchebnyye materialy po voprosam stantsii "Pentakonta 1000S" [Instructional materials on questions of the "Pentakonta" 1000S], Warsaw, 1978.

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COMMUNICATIONS EQUIPMENT USED FOR CENTRALIZING PRINTING OF LOCAL NEWSPAPERS

Moscow ELEKTROSVYAZ' in Russian No 2 1980 pp 15-18

[Article by B. M. Sobolev and V. A. Uzilevskiy: "Employment of Communications Equipment for Centralization of Printing of Rayon Newspapers" (Published as a discussion)]

[Text] The experience of the USSR and foreign countries indicates the effectiveness of employment of communications equipment and technology in producing and publishing newspapers, magazines, and various information publications. Modern communications equipment makes it possible not only flexibly and efficiently to transmit printed information but also to combine editing and printing processes into a continuous production cycle. Thanks to this it is possible to accomplish an important political-economic task -- concentration of printing involved in putting out local (rayon and city) newspapers, which will make it possible to adopt offset printing and photocomposition, and consequently substantially to improve the quality of newspaper printing. The extensive adoption of offset printing and photocomposition in the Soviet printing industry is specified in the resolutions of the 25th CPSU Congress.

General information. At the present time there are approximately 3,000 rayon and municipal print shops in this country. More than 50% of these print shops are small enterprises with from 5 to 20 employees [2]. This fact makes difficult incorporation of modern equipment and processes in rayon printing plants, which is reflected in the quality of printing of the newspapers they put out. A lack of highly-skilled personnel is another problem for small printing plants remote from industrial centers.

In spite of their small output capacity, unless outside work is taken on, rayon printing plants are frequently only partially work-loaded and therefore operate at a loss, since as a rule local newspapers have small circulations (5-15 thousand copies) and are published only three or four times a week. Printing of blank forms and other items, although improving the economic performance of printing plants, is contrary to a policy of specialization and concentration of printing activities. Alongside the expediency of employing high-productivity equipment in small print shops, one must also take into consideration the extremely low effectiveness of capital investment in construction of small rayon printing plants [2].

Thus establishment of new printing facilities for printing local newspapers meeting today's demands is a problem of vital importance. Its solution lies in centralizing the printing of local newspapers at large inter-rayon, municipal and oblast printing plants.

It is necessary to determine how to deliver materials from newspaper offices to the printing plant and proofs from the printing plant to the newspaper office for proofing and final editor approval, as well as how to get the finished papers to the readers. Trucks can be used for these purposes, as is done in the GDR, for example, only with short distances, good road and climatic conditions. A major inconvenience in this case, however, is the trips newspaper personnel must make to the printing plant; this is confirmed by the experience of the newspaper LADOGA in Kirovskiy Rayon, Leningradskaya Oblast, which is located at a distance of only 30 kilometers from the Tosno Printing Plant, where for many years this newspaper was composed and printed. On publishing day, that is, three to four times a week, the editor would spend approximately 5 hours on travel to the printing plant. In addition, a lack of continuous communications complicated composing, adjustment and sheet proofing during the entire newspaper production cycle.

Therefore centralization of the printing of local newspapers with employment of communications equipment is optimal. In this case newspaper materials (text, illustrations, layouts) are transmitted by communications equipment to a central printing plant, where all printing operations are performed. Before the presses begin to roll, proofs are transmitted to the newspaper offices. There they are examined by the editor and approved. The editor-signed approved copy is transmitted by fascimile equipment to the printing plant.

Preliminary calculations have indicated that the economic effectiveness of centralization is directly proportional to the number of newspapers printed at a single printing plant. In addition, concentration of production will lead to a substantial decrease in number of employees and units of equipment, while retaining production volume. Economic effect is obtained due to concentration of production and reduction of capital investment in construction of new rayon printing plants in spite of the fact that additional expenses are incurred in leasing communication lines and communications equipment operation. There are several possible variants of organization of a system of centralized newspaper printing employing communications equipment. Let us examine the two most effective arrangements: 1) typed originals, layouts, and proofs are transmitted only with the aid of facsimile equipment; 2) prior-encoded originals are transmitted with the aid of data transmission equipment (APD), layouts and proofs by facsimile equipment, with the data carrier punched tape or magnetic tape (magnetic cards). These versions differ not only in type of communications equipment utilized but also in character of editing-publishing processes. The principal tasks of organization of electronic and postal communications, however, are identical for both variants as applied to the system of centralized printing of local newspapers.

Principles of organization of communications. When selecting an electronic communications network arrangement for organizing transmission of materials between local newspaper offices and a central printing plant, it is essential to take into consideration the existing structure of intraoblast communications and a future zone primary network. It is therefore most expedient to locate the central printing plant which prints local newspapers in the oblast seat, and most optimally existing oblast newspaper printing plants. Dispatching and delivery of local newspapers should be handled together with oblast and central newspapers: dispatching -- at existing newspaper dispatching facilities, and hauling -- by postal truck and rail routes. Of course in many cases it will be necessary to enlarge dispatch operations and increase the number of vehicles employed.

Maximum distance between local newspaper offices and oblast printing plant should not exceed 200-250 km, which makes it possible, in case of electrical communications breakdown, to deliver newspaper materials from the newspaper offices to the printing plant by car or train without missing local newspaper printing deadline or disrupting newspaper delivery schedules.

As an exception, in geographically large oblasts local newspapers can be centralized-printed at an interrayon printing plant located on oblast and central newspaper postal delivery routes. Otherwise local newspapers must be transported to rayon postal distribution centers by newspaper or printing plant motor transport.

Experimental projects conducted by the problems laboratory of LEIS [Leningrad Electrical Engineering Communications Institute] jointly with KONIIS [Kiev Branch of the Central Scientific Research Institute of Communications], LGTS [Leningrad City Telephone Network] and Leningradskaya Oblast PTUS [Postal-Telegraph Communications Administration] to establish in Leningradskaya Oblast a system of centralized printing of local newspapers indicated that utilization of communication channels the parameters of which meet standards in conformity with the requirements of YeASS [Unified Automated Telecommunications Network of the Soviet Union] ensures the requisite quality of transmitted materials.

Facsimile equipment and data transmission equipment operate on tone frequency (TF) channels, which can be schedule-leased to newspaper offices; when channel occupation time does not exceed 15-20 minutes during a single transmission session, operation on a switched network is possible.

Extensive adoption of centralized newspaper printing with employment of communications equipment will require solving the problem of servicing the terminal equipment installed at newspaper offices and printing plants. Since this will be subscribed-operation equipment, it should be operated by newspaper office and printing plant personnel; equipment servicing and repair can be handled either by enterprises of the Goskomizdat system or on a contractual basis by rayon and oblast communications enterprises.

Newspaper transmission by facsimile equipment. The simplest version of centralization of newspaper printing from an organizational standpoint is shown in Figure 1. In this instance employment of facsimile equipment introduces no changes either in editing or printing processes. Equipment with plain-language entry provides transmission of text originals and layouts, while transmission of half-tone illustrations is handled by Neva or Pallada type photorecording equipment [3].

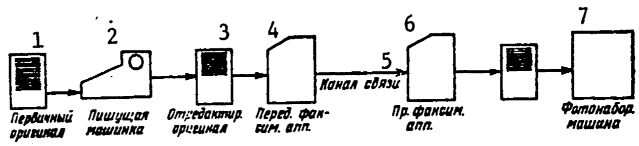

Figure 1.

Key:

1. Original
2. Typewriter
3. Edited original
4. Facsimile transmitting unit
5. Communication channel
6. Facsimile receiving unit
7. Phototypesetting machine

As early as 1974 the LEIS problems laboratory, working jointly with the Publishing Houses, Printing Plants and Book Trade Administration of the Leningradskaya Oblast City Executive Committee and the Leningradskaya Oblast PTUS, conducted experiments in centralizing printing of local newspapers with utilization of standard facsimile equipment.

During these experiments original typed texts and layouts were transmitted with a Shtrikh unit [5], while illustration originals were transmitted by a Neva half-tone image transmission unit with an FM adapter developed at the LEIS problems laboratory. Column proofs for editing and approval were transmitted from the printing plant to the newspaper offices with a Neva unit. The experiments showed that the Shtrikh unit does not meet the requirements of the newspaper staff -- too much time is expended on transmission (approximately 7 hours); it is necessary to keep a special operator to work the receiving unit. In addition, due to poor image resolution, the Shtrikh unit proved unsuited for transmitting newspaper proofs for editor approval.

Table

Specification Items	Specification Figures for Unit		
	Shtrikh (USSR)	Infotek-6000 (FRG)	Kopix-9600 (Hungary)
Type of unit	Facsimile, for transmitting and receiving line images		
Method of transmission and receiving	Single-band duplex		Duplex
Communication channel utilized	Tone frequency		
Type of scan	Drum	Flat	
Resolution, min/mm	3.8	2.7, 4, 8	4, 8
Method of recording	Electromechanical, ink on paper	Electrostatic on dielectric paper	
Maximum format of transmitted document, mm	210 x 297	210 x 356	280 x 420
Developing method	-	Liquid	Powder
Transmitting time for a document of 210 x 297 format	6 and 12 min	35, 60, 120 sec	30 sec

For this reason the high-speed Infotek-6000 facsimile unit (FRG) was tested. It offers high-speed transmission on an assigned or switched tone frequency channel of line originals (typed and handwritten texts, diagrams, graphs, drawings, etc) with a high quality of reproduction at the receiving station. The Infotek-6000 employs modern methods of line and frame signal compression. Thanks to this unit, the time required to transmit the materials for a single issue was reduced more than threefold. Semiautomatic loading of the original copy and operatorless receiving considerably improved operation of the entire system. Amplitude frequency response and amplitude characteristic measurements were taken in the process of testing the equipment, as well as measurements of interference level and tone frequency channel high-frequency train residual attenuation at a frequency of 800 Hz. The tests showed that instability of channel residual attenuation exerts the greatest influence on quality of transmission. For example, excessively high signal levels (measurements were made at a point +4.3 db of the communication channel relative level) lead to distortion of a portion of the information blocks, which in turn leads to loss of a portion of the lines on the copy. When signal level exceeds the standard level by more than 4.3 db, these distortions become so significant that transmission breaks off. At the same time excessively low levels (to -4.3 db at a point +4.3 db of the relative level) do not affect transmission stability and quality.

Operation of an Infotek-6000 unit over the course of a year indicated that its utilization does not lead to changes in organization and process of putting out a newspaper either at the newspaper offices or at the printing plant.

The equipment operated reliably both on assigned and switched channels, and the quality of the copies was satisfactory both to typesetters and editors.

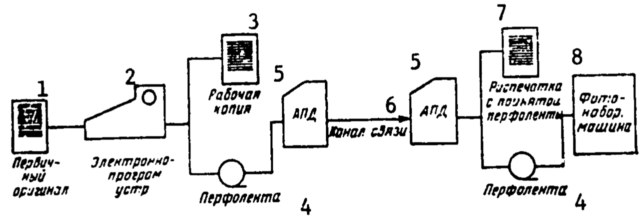

Figure 2.

Key:

1. Original
2. Electronic programming device
3. Working copy
4. Punched tape
5. Data transmission unit
6. Communication channel
7. Printed copy from received punched tape
8. Phototypesetting machine

Transmitting newspapers with data transmission equipment. This variant of centralized printing of local newspapers (Figure 2) involves significant changes in editing-publishing and printing processes. The bulk of materials (text originals) are encoded, and then, in the form of punched tape or magnetic tape, are transmitted by data transmission equipment. Encoding and preparation of data are done on electronic-programming or coding equipment, which makes it possible to obtain partially coded or fully coded punched tape. The latter, in addition to information proper, contains data (in coded form) on typeface and point size, composing format, and the entire text is broken down on the tape into lines of one and the same format. Punched tape is used at the receiving station for direct control of the automatic typesetting machine or phototypesetting machine. Special operator training is required to prepare a fully-coded punched tape, while a newspaper office typist can prepare a partially-coded punched tape simultaneously with retyping the text. Layouts, illustrations and proofs are in this case transmitted by facsimile equipment.

Coded text originals are transmitted from local newspaper offices to the oblast printing plant either by the PD-200 network or, just as in facsimile transmission, by the existing public telephone system (TF-OP). In both cases the data transmission equipment operates on assigned or switched channels.

At the terminal station TAP-2 equipment, which is extensively employed in this country, can be hooked up for operation on the PD-200 network, and on the TF-OP system -- Soviet-built type Mikro A high-speed data transmission equipment [6], as well as the Akkord 1200 or experimental 1200 Sbor data transmission equipment [7].

In the process of testing TAP-2 equipment, in transmitting the local newspaper KIRISHSKIY FAKEL to the Leningrad Telegraph Office the degree of synchronous distortions in the channel did not exceed 10%, and system real information capacity comprised 166-170 bits per second, which is in good agreement with the rated figure (172 bits per second). One issue of the local newspaper, the information volume of which is 70,000 print characters (560 kilobits with an 8-bit code) was transmitted in 55 minutes.

Tests showed that operation at a rate of 200 Baud with a block length of 260 bits is impossible due to the high frequency of queries and their considerable duration. The number of check bits placed in a block in this mode remains the same as with a 140-bit block -- 16 bits per block, which leads to less redundancy in the block (6.1 in place of 11.4%) and to decreased signal noise immunity.

It is most effective to transmit text information from newspaper offices to the oblast printing plant by public telephone lines with a Sbor high-speed data transmission unit. A Sbor data transmission unit with punched tape I/O devices was installed in an experimental system for centralized printing of local newspapers. Transmission time from newspaper office to printing plant for a 1,000 character capacity punched tape (with a 7-bit code) ranged from 50 to 90 seconds, depending on channel quality, which corresponds to a circuit carrying capacity of 44.5-80 characters per second. For example, with a channel carrying capacity of 80 characters per second, with a bit error factor of 10^{-2}, it took 14.5 minutes to transmit the materials of an entire issue.

Regular centralized printing of the KIRISHSKIY FAKEL local newspaper at the Leningradskaya Oblast Printing Plant imeni Volodarskiy, employing Sbor data transmission equipment, began in October 1979. The newspaper's expenses on leasing communication channels and typesetting processes were considerably less than with utilization of facsimile equipment. A partially-coded punched tape, prepared at the newspaper offices by a typist and transmitted to the printing plant by Sbor equipment, constitutes a program for automatic newspaper composing on a Soviet-built FA-500 automatic phototypesetting machine [8].

Conclusion. The experimental system of centralized printing for local newspapers established in Leningradskaya Oblast makes it possible to elaborate the main points and to work out different centralization process versions under actual production conditions; to resolve numerous organizational-standardizing questions arising as a result of changes in the editing-publishing process and equipping newspaper offices and printing plants with communications equipment; to refine centralized newspaper printing technical-economic effectiveness indices; to formulate specific technical requirements on data transmission equipment and facsimile equipment.

But some conclusions can already be drawn. In view of the radial-center principle of layout of long-distance communication networks and postal communication routes prevailing in this country, it is most expedient to centralize printing of local newspapers on the basis of oblast printing plants. In those cases where this is impossible for any reason, inter-rayon printing plants must be located taking into consideration oblast and central newspaper delivery routes, as well as communications network layout.

At the first stage of adoption of a centralized newspaper printing system it is advisable to employ facsimile equipment to deliver all materials from newspaper offices to printing plant. It is more efficient, however, to transmit text materials by Sbor data transmission equipment.

Bibliography

1. Yablokov, M. N. "Communications Equipment and Development of a System of Decentralized Printing of Periodical and Information Publications" ELEKTROSVYAZ', No 11, 1973.

2. Sorkin, M. F. "Ways to Centralize Printing of Local Newspapers," POLIGRAFIYA, No 9, 1977.

3. Osherov, V. Ye. "Pallada Facsimile Equipment," ELEKTROSVYAZ', No 7, 1974.

4. Georgiyev, A. I. "The Kirishi-Volkhov Experiment," ZHURNALIST, No 10, 1975.

5. Korol', V. I., et al. "The Shtrikh-M Ink-Printing Facsimile Unit," ELEKTROSVYAZ', No 2, 1973.

6. Pshenichnikov, A. M. et al. "APD-Mikro A Data Transmission Equipment," ELEKTROVSYAZ', No 8, 1975.

7. Rozhkov, L. I. "Sredstva peredachi dannykh v ASU" [Automated Control System Data Transmission Equipment], Kiev, Tekhnika, 1977.

8. Uzilevskiy, V. A. "Phototypesetting System for Transmitting Newspapers by Communication Lines," ELEKTROSVYAZ', No 1, 1976.

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HIGH SPEED FACSIMILE TRANSMISSION SYSTEM DESCRIBED

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[Article by Yu. Ya. Shats, V. I. Drozdov, N. I. Stepanets, L. G. Guzhba, O. V. Tolstosheyev and I. M. Klinovskiy: "High-Speed Facsimile Transmission System"]

[Text] Continuous increase in the rates of transmission of black-and-white line images is leading to the necessity of developing systems which ensure a decrease in information redundancy and matching of high scanning rates with the limited carrying capacity of a data transmission channel. Reduced redundancy in such systems is achieved by means of binary coding of the transmitted image, and matching of system and channel rates is achieved by introducing a switched buffer memory and feed pitch delays [1].

We shall describe below such a system, intended for transmitting weather maps (black-and-white) at a scan rate of 960 lines per minute, feed pitch of 0.265 mm/line and a resolution of 3.1 lines per mm on a data transmission channel with a channel capacity of 4800 bits per second. This system makes it possible to decrease from three to fivefold tone frequency channel transmission time for weather maps in comparison with the presently-employed FAK-DM and FAK-P facsimile equipment, which operates primarily at a scan rate of 120 lines per minute.

A line code is employed in the facsimile transmission system. A scan line 480 mm in length contains 1,500 picture elements (PE), the first 80 of which comprise the matching sector, and the remaining 1,420 -- the useful portion of the line. The useful portion of a line breaks down into white and black segments; the first white segment of the equalization and synchronization sector begins with the 10th PE and ends with the appearance of a black segment in the useful portion of the line.

Line coding begins with formation from the first nine PE of the equalization and synchronization sector of a nine-bit word of the form 010000000. A white segment is then coded, a segment which includes 71 PE of the equalization and synchronization sector, and if the segment length is equal to 63 n PE (n=2, ...23), it diminishes by one PE with a simultaneous increase in the length of the following black segment by one PE.

Coding is performed in 6-bit words: a white segment is represented by n words if its length is greater than 63 (n-1) PE and less than 63 n PE (n= 1, ...24); all words with the exception of the final word are of the form 111111, while the last word must contain at least one 0, indicating end of coding of the white segment and transition to coding of a black segment.

When coding a black segment, in case its length is equal to 7 n PE (n=1, ..., 202) it is decreased by one PE, and the length of the following white segment increases at the same time by one PE. Coding is done by 3-bit words: a black segment is represented by n such words if its length is greater than 7 (n-1) PE and less than 7 n PE (n=1, ... 203); all 3-bit words other than the last word have the form 111, while the last word must contain at least one 0, indicating end of coding of the black segment and transition to coding of a white segment.

Table 1

Длина отрезка l, ЭИ (1)	Кодированные черные отрезки с 3-битовым кодовым словом (2)								
	2^2	2^1	2^0	2^2	2^1	2^0	2^2	2^1	2^0
1	0	0	1						
2	0	1	0						
3	0	1	1						
4	1	0	0						
5	1	0	1						
6	1	1	0						
7	1	1	0						
8	1	1	1	0	0	1			
9	1	1	1	0	1	0			
10	1	1	1	0	1	1			
11	1	1	1	1	0	0			
12	1	1	1	1	0	1			
13	1	1	1	1	1	0			
14	1	1	1	1	1	0			
15	1	1	1	1	1	1	0	0	1

Key:
1. Length of segment i, PE
2. Coded black segments with 3-bit code word

Table 1 contains examples of coding of black segments. The lengths of code words (number of bits) for white $m_б$ and black $m_ч$ segments, as well as the structure and length of the phase word for the selected code were determined from the condition of providing it with maximum compensating capability, that is,

$$k\,(m_б,\ m_ч,\ m_ф) = \frac{Q}{Q_б\,(m_б) + Q_ч\,(m_ч) + Q_ф\,(m_ф)}, \quad (1)$$

where Q is the total volume of uncoded information on a weather map;

$Q_б(m_б)$, $Q_ч(m_ч)$ -- volumes of coded information of white and black segments; $Q_ф(m_ф)$ -- volume of information on position of equalization and synchronization sector, determined as

$$Q_ф\,(m_ф) = m_ф D r_п = 1824\, m_ф. \quad (2)$$

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Here D=480 mm -- length or width of weather map, r_{π}=3.8 lines/mm -- system resolution in direction of feed. Total volume of uncoded information on the weather map is

$$Q = L D r_p r_n = 2{,}72 \cdot 10^6, \qquad (3)$$

where L=480 mm -- length of scan line, r_p=3.1 lines/mm -- system resolution in direction of scanning.

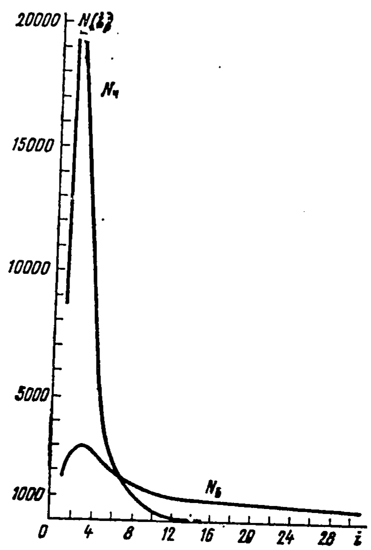

Figure 1.

Figure 1 contains distributions of lengths of white and black segments of a typical weather map $N_{\sigma}(i)$, $N_{\text{ч}}(i)$. The distributions represent the numbers of white and black segments with lengths i varying from 1 to 1500 PE. With the aid of a computer we calculated

$$\left.\begin{aligned} Q_{\text{б}}(m_{\text{б}}) &= m_{\text{б}} \sum_{S=1}^{S^*_{\text{б}}} S \times \\ &\times \sum_{i=(S-1)(2^{m_{\text{б}}}-1)+1}^{S(2^{m_{\text{б}}}-1)} N_{\text{б}}(i), \\ Q_{\text{ч}}(m_{\text{ч}}) &= m_{\text{ч}} \sum_{S=1}^{S^*_{\text{ч}}} S \times \\ &\times \sum_{i=(S-1)(2^{m_{\text{ч}}}-1)+1}^{S(2^{m_{\text{ч}}}-1)} N_{\text{ч}}(i), \end{aligned}\right\} \qquad (4)$$

where $S^*_б$ and $S^*_ч$ -- least whole numbers (when $S \geqslant S^*_б$ and $S \geqslant S^*_ч$ the second sums in each equation of formula (4) are equal to zero). Calculations were performed for $m_б$, $m_ч$=2, ..., 12, and their results are contained in Table 2. With the aid of this table we calculated values $m_б$ =6; $m_ч$ =3, minimizing $Q_б(m_б)$ and $Q_ч(m_ч)$ respectively.

For determination of phase word form and length it was taken into account that any group containing less than 9 bits, with the selected code, must contain at least two 1. Minimization of $Q_Ф(m_Ф)$ is ensured by selecting length $m_Ф$ =9, whereby a phase word of the form 010000000 is always distinguishable, since it consists of eight 0 and one 1.

Table 2.

m	2	3	4	5	6	7	8	9	10	11	12
$Q_б \cdot 10^{-5}$	9,07	6,28	4,58	3,72	3,40	3,53	3,76	4,21	4,68	5,15	5,60
$Q_ч \cdot 10^{-5}$	1,61	1,57	2,01	2,45	2,96	3,46	3,95	4,45	4,95	5,43	5,92

On the basis of Table 2 and formula (2) we find

$$\min Q_б(m_б) = Q_б(6) = 3{,}40 \cdot 10^5, \text{ bits};$$
$$\min Q_ч(m_ч) = Q_ч(3) = 1{,}57 \cdot 10^5, \text{ bits};$$
$$\min Q_Ф(m_Ф) = Q_Ф(9) = 1824 \cdot 9 = 0{,}16 \cdot 10^5, \text{ bits}.$$

Taking into consideration (3), with formula (1) we shall obtain

$$\max k(m_б, m_ч, m_Ф) = k(6;\ 3;\ 9) = \frac{2{,}72 \cdot 10^6}{(3{,}40 + 1{,}57 + 0{,}16) \cdot 10^5} = 5{,}3.$$

System operating principle. The transmitter of a facsimile system, a block diagram of which is contained in Figure 2, consists of analyzing device АУ, phase pulse sensor ДФ, image coder КИ, phase pulse coder КФ, record keys $КЗ_1$ and $КЗ_2$, memories $ЗУ_1$, $ЗУ_2$, read keys $КС_1$, $КС_2$, monitoring and control devices УКУ, and modulator М, the output of which is connected to the communication channel.

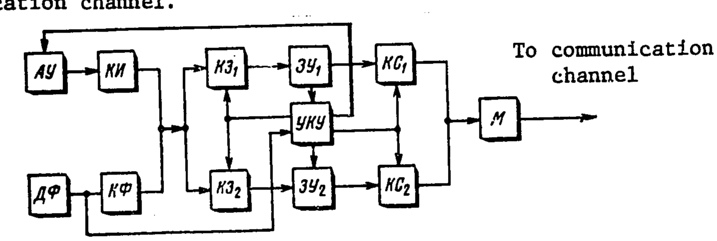

Figure 2.

The analyzer performs line-by-line analysis of the transmitted image, which is coded in the КИ. At the beginning of the equalization and synchronization sector of each scan line the ДФ shapes the phase pulse, which is coded in the КФ. The aggregate of coded pulses and lines passes through КЗ$_1$ or КЗ$_2$ sequentially into ЗУ$_1$ or ЗУ$_2$. This set is further transmitted through KC$_1$ or KC$_2$ to M, where it is modulated before being fed into the communication channel. The YKY monitors reading of information from ЗУ$_1$ and ЗУ$_2$ at the moment of phase pulse arrival and controls the step motor feed pitch to AY and sequential connection of КЗ$_1$, KC$_2$ or КЗ$_2$, KC$_1$.

Transmitter operation can be broken down into cycles. In the initial state ЗУ$_1$ and ЗУ$_2$ are free.

The first cycle begins at the moment of appearance at ДФ output of the first phase pulse, which registers the first transmitted line and through YKY sets ЗУ$_1$ in record mode, ЗУ$_2$ in read mode, and AY in step motor normal feed mode.

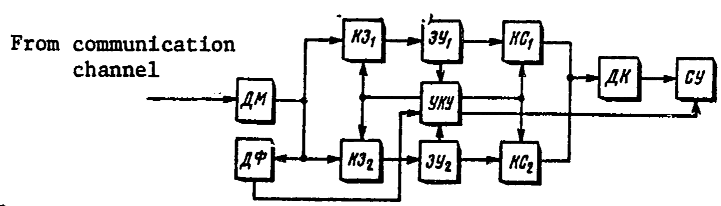

Figure 3

The first phase pulse and line, transmitted in code form (in volume Q_1) are entered in ЗУ$_1$ through open КЗ$_1$. Here

$$Q_1 = q k_1 = q_1, \qquad (5)$$

where

$$\left.\begin{aligned} 0 \leqslant k_1 \leqslant k, \\ 0 \leqslant q_1 \leqslant q, \\ q = C/N, \end{aligned}\right\} \qquad (6)$$

if the entire volume of ЗУ$_1$ (ЗУ$_2$) is broken down into k+1 blocks with identical volumes q and if we designate with C channel capacity, bits per second, and with N -- AY scanning rate, lines per second. Number k_1 is stored in YKY. Logical zeroes of volume q are read through open KC$_2$, and after modulation in M are transmitted into the communication channel.

At the moment of appearance at ДФ output of the second phase pulse, YKY changes ЗУ$_1$ to read mode sets ЗУ$_2$ in record mode if k=0 or stand by to record if $k_1 \geqslant 1$, and sets in AY normal feed mode if k_1=0, or delayed feed mode if $k_1 \geq 1$. For $k_1=0$, when the second transmitted line is determined by the second phase pulse, second phase pulse and line are entered through open K3 2 in code form of volume Q_2, for which representations (5) and (6) are correct if one changes from subscript 1 to 2. The number k_2 is stored in YKY, and capacity $Q_1=q_1$ from the first transmitted phase pulse and line, as well as capacity $q-q_1$ of logical zeroes is read from $3Y_1$ through open KC_1. Following modulation in M, all read information is fed into the communication channel.

At the same time, for $k_1 \geq 1$, when the second transmitted line is determined by the (k_1+2) phase pulse, prior to its appearance at Дф output from $3Y_1$, capacity qk_1 from the first transmitted phase pulse and line is read and $3Y_2$ entry standby mode is maintained, as is delayed feed mode into AY. With the appearance of (k_1+2) phase pulse at Дф output, YKY changes $3Y_2$ into record mode and establishes normal feed mode in AY. After this $3Y_2$ is loaded with the second phase pulse and line transmitted in code form, while $3Y_1$ is freed of the last q_1 bit of the first transmitted pulse and line, just as when $k_1=0$.

The second transmitter operating cycle begins at the moment of appearance at Дф output of the (k_1+3) phase pulse, which through YKY shifts $3Y_2$ to read mode, sets $3Y_1$ in write mode if $k_2=0$ or write standby mode if $k_2 \geq 1$, and secures in AY normal feed mode if $k_2=0$ or delayed feed mode if $k_2 \geq 1$. The second cycle differs from the first only in the fact that Q_2 bits are read from $3Y_2$ through open KC_2 in place of q logical zeroes, modulating in M and feeding into the communications channel.

The receiver of the facsimile transmission system, a block diagram of which is contained in Figure 3, consists of demodulator DM, the input of which is connected to a communication channel, Дф, $K3_1$ and $K3_2$, $3Y_1$ and $3Y_2$, KC_1 and KC_2, YKY, image decoder ДK, and synthesizer CY.

A signal from the communication channel is demodulated in DM and is fed through $K3_1$ and $K3_2$ sequentially into $3Y_1$ or $3Y_2$, and from there through KC_1 or KC_2 into ДK, where it is decoded. The decoded signal is recorded in CY, which performs a line-by-line synthesis of the received image. Monitoring of loading of $3Y_1$ and $3Y_2$ at the moment of phase pulse arrival from Дф is performed by YKY. The latter controls motor feed pitch in CY and sequential connection of $K3_1$, KC_2 or $K3_2$, KC_1. The receiver operates in cycles. In the idle state $3Y_1$ and $3Y_2$, which are analogous to transmitter $3Y_1$ and $3Y_2$, are free.

The first cycle begins at the moment of appearance in Дф of the first phase pulse, which determines the first received line, and through YKY sets $3Y_1$ in write mode, $3Y_2$ in read mode, and CY into normal feed mode. The first phase pulse and line of volume Q_1, received in code form, are recorded in $3Y_1$ through open $K3_1$, in the form of k_1+1 blocks of volumes q, whereby the $(k_1 + 1)$ block contains $q-q_1$ logical zeroes. YKY time-compares completion of entry of each block with appearance of the second phase pulse in Дф and establishes normal feed mode in CY if $K_1=0$, or delayed feed mode if $k_2 \geq 1$. Volume q of logical zeros is read from ЗY_2 during first-block recording in ЗY_1 through open KC_2; these logical zeros, passing through ДK, are recorded in CY in the form of a white segment.

At the moment of appearance in ДФ of the second phase pulse, which determines the second received pulse and line, YKY stops information entry into ЗY_1 on the (k_1+1) block, sets ЗY_1 to read mode and ЗY_2 to write mode, and CY to normal feed mode. The second pulse and line, received in code form of volume Q_2, are recorded in the form k_2+1 blocks of volumes of q bits in ЗY_2 through open KЗ 2, whereby the (k_2+1) block contains q-q_2 logical zeros. YKY time-compares end of entry of each block with appearance of the third phase pulse in ДФ and sets normal feed mode in CY if k_2=0 or delayed feed mode if $k_2 \geq 1$. Volume Q_1 from the first received phase pulse and line is read during entry of the first block in ЗY_2 through open KC_1. This volume of information is decoded in ДK and recorded in CY.

The receiver second cycle begins at the moment of appearance in ДФ of the third phase pulse, which determines the third received line and through YKY sets ЗY_1 in write mode, ЗY_2 in read mode and CY in normal feed mode. This cycle differs from the first cycle only in the fact that volume Q_2, which is decoded in ДK and recorded by CY, is read from ЗY_2 through open KC_2 in place of volume q logical zeros.

System implementation and testing. The transmitter employs as an AY a drum-type device with scanning line length of 480 mm, 5-percent equalization and synchronization sector, scan rate N=16 lines per second, feed pitch 0.265 mm/line, and resolution 3.1 lines/mm. Scanning drive is provided by a type GSD 531-6 hysteresis motor, which operates at 4800 rpm and is powered by voltage with a frequency of 240 Hz. A type ShD-5 D 1M step motor powers feed, operating at 400 rpm and powered by voltage with a frequency of 1600 Hz. Its feed pitch can be reduced fourfold by shifting power supply to voltage with a frequency of 400 Hz. Weather map analysis was performed by a photoelectric converter, which includes a type FEU 84-3 photomultiplier tube, a rectangular raster diagram of dimensions 0.18 and 0.2 mm in the direction of scan and feed, and a type OP 8-9 incandescent lamp as light source. The system's resolution was provided by breaking down the picture signal to 1500 PE per scan line by 24 kHz frequency pulses. Frequency instability did not exceed 1×10^{-7} relative units.

A flat-type device with contact recording (with a flexible electrode) of the image on a roll of type EKhB-V electrochemical paper was employed in the receiver as CY. The CY has the same parameters as the AY. The transmitter phase pulse sensor employs an FD-27K photodiode and a type SG -28-0.05-1 incandescent lamp. The receiver's phase discriminator is a 9-bit input register to which a lockon circuit is connected, which discriminates code words of the form 010000000.

The image coder and decoder employ Logika-2 series microcircuits. Each 900-bit memory consists of three blocks and is connected sequentially for write or read.

The modulator and demodulator provide a data transmission and receiving capability of 4,800 bits per second, so that q=300 bits per line.

In testing the system with off-line transmitter and receiver synchronization, transmission time for a standard 480 x 480 mm^2 weather map was 2 minutes 54 seconds with an acceptable quality of reproduction: incompletion of individual lines was less than 2%, lines which contained more than 600 bits of coded information. There occurred an insignificant (1.3 cm) change in copy length in comparison with the original due to inertia of the optical carriage mechanism in the transmitter analyzer.

Experiments indicated that in this system the total number of uncompleted lines may be less than 1% by only doubling buffer memory, while copy elongation can be reduced to 2-3 mm by reducing optical carriage inertia with replacement of the photomultiplier tube with a photodiode [2]. Since the selected code restricts occurrence of errors within a single line, and the volume of transmitted coded information does not exceed 5.13×10^5 bits with modem error detection not less than 1×10^{-4} during weather map transmission cannot be more than 52 distorted lines. This comprises less than 2.8% of the total number of lines (1,842) and is practically half as many as the allowable number of distorted lines (5%).

Thus the described system of high-speed facsimile transmission makes it possible to reduce the information redundancy of weather maps and to match high scan rates with limited data transmission channel capacity.

Bibliography

1. "Sbornik tekhnicheskoy informatsii po voprosam svyazi" [Technical Information Series on Problems of Communications], Moscow, Gidrometeoizdat, 1975, No 13.

2. Shats, Yu. Ya., et al. "Analyzer With Silicon Photodiode for a Facsimile Transmitter," ELEKTROSVYAZ', No 8, 1977.

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