

RADIOWAVE INFORMATIVE-CONTROL SYSTEM for MAGNITOLEVITATIVE VEHICLES with ELECTRODYNAMIC SUSPENSION

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Abstract

It is presented conception of the building of the radiowave informative-control system for magnetolevitative vehicles on the base of the use the electromagnetic waves of super-high-frequency (SHF) (mm-waves) range. The sysem includes marker-communicative magistral waveguide, established along active travel structure, having the apertures for the communication with SHF-generator, established on platform, ultrafast withoutcontact autogenerative meters of the distance between platform, active travel structure and lateral directing. These meters solve the problem of the determination of the spatial position of the vehicle. The control system contains the autogenerative meters of the magnetic field in backlash with an opportunity of transfer of the information on the radiochannel as well as contains the device of an information handling and control of the active travelling structure excitation coils.

In spite of the fact that the electrodynamic suspension has own capacity to stabilize the levitative motion [1], the informational-control system of a transport means with this type of suspension is its relevant constituent and the role of the indicated system specially is relevant at the stage of designing and testings of a transport means. In Ukraine experimental samples of transport means with a magnetic levitation and testing grounds are built, however intrusion of this doubtlessly perspective transport is integrated to necessity of a management development, which would allow for specificity of selected version of the magnetic suspension. Practically each implementator of a system with a magnetic levitation designs an own management system [2, 3]. The researches, conducted in this direction, have allowed to reveal specificity of a management system for the indicated type of transport, complexity in its implementation both in a part of separate clusters of units, and in understanding the philosophy of a management system. The concepts, transferred from a tradishional railway transport, and, quite often, apparatuses constructions [2] do not decide specific problems arising at control by crews, wich levitate at a small altitude above travelling frame and move with a high speed.

Really, the existing submissions about monitoring and management systems for transportation facilities of traditional type base on usage as velocity and acceleration sensors of measuring transducers of a different type (rheostatic, capacitive, thermal, light, ionization, tensoresistive) and do not content in a full volume to a costing problem neither on response, nor on accuracy. For example, as the implementators of a management system of the transport with a magnetic levitation MLV consider, even improved for concrete application piezoaccelerators (piezotrons) can not be used for measurement of small accelerations because of a zero drift and low sensitivity, for measurements of constant acceleration because of small voltage output, high internal resistance, owing to what their main performance figures are low-level. For measurement of vibration displacements, vibration rate, small, large, uniform accelerations, average and the instantaneous velocities of motion, horizontal and vertical gaps diversified transformers distinguishing on a design, on a principle of operation, on nature of output signals are designed. Besides the elements and clusters of a management system should be steady against effect of variables electrical and magnetic fields, which are always in a gap between a transport means and fissile travelling frame, against troughs of travelling frame, to not introduce additional errors and to actuate

engineering solutions ensuring stability of the main clusters and units to mechanical and temperature loads. Therefore, the creation of an integrated system of the control and mission control of transportation facilities with the magnetic suspension with on the base of the traditional approaches looks problematic.

At the selection of the law controlling the suspension the design of a mechanical part of crew should be known and on the given research stage it is possible to construct a control algorithm in the supposition, that the superconducting magnetic units, dolly and body are connected by means of elastic suspension and at usage of the decentralized control system of gaps, when each point of suspension executes own functions independently and separately from each other.

By the stored writers of the present report considerable experience in a part of designing of contactless meters of small movements, flowmeters, indicators of demarcations of mediums, including non-steady, meters of large and small accelerations with usage of radiowave methods, high-stable steady against mechanical and temperature overloads autooscillators on semiconductive diodes, indicators and meters (receivers) of radiowave radiation, electrocontrolled phase-changers, and also available information on management systems of MLV abroad [3] indicate paths of creation of management systems of MLV on the magnetic suspension on the basis of usage of electromagnetic oscillations of range of superhigh frequencies, transference lines of the composite nonconventional forms, small-sized semiconducting sources of electromagnetic waves. The creation of the unitized radiowave device for the control of a broad spectrum of object motion parameters, its position on a route would allow to reduce the cost price of its manufacturing, nomenclature of furnishing elements, to lower costs of exploitation, to increase reliability. In the given report the concept of a radiowave informational-control system (RICS) of mission control of a transport means with a magnetic levitation is added, the principle of construction of a marker-connected wave-guide line, as basic component of RICS is set up. And though all primary sensors of spacing interval, speed, acceleration, vertical and horizontal gaps, vibration accelerations can be constructed on radiowave principles, the fulfilment of some functions under certain conditions (predominantly outgoing from cost reasons or for usage as a back-up means) is expedient for executing also with usage of diverse methods. Therefore real system of control can actuate also usage of highly sensitive sensors of a gap (vertical, horizontal) with usage of sensors of magnetic fields switched on by a special image, inductive sensors of side drifts, devices for scheduled and emergency stoppage of a transport means. That is, the designing of management system for transport means with magnetic levitation actuates usage of the miscellaneous physical phenomena which have been trusted to in a system, designing of submachines and units, manufacturing, layout of a system and approbation it on an actual, full scale transport means, check of the concepts, trusted to in system development, updating of the structural or functional schemes, of design solutions of separate components of a system.

At the same time the indispensable stage in system development should be realization of researches on designing of system of management by *models* of transportation facilities driving with speeds, instituted by sizes of polygon (basically - by low speeds). That is, the working version of a management system of full scale MLV is a product of careful experimental researches on models MLV in conditions of polygon with length of a route in some tens meters, where the running speeds about units of meters one minute can be realised. Naturally, that the developed management system by polygon model should be corresponded (under the cost and complexity of engineering solutions) to this individual problem and consequently has definite specificity, but the main positions of the indicated system, its components should be equivalent to a management system of a full scale transport means.

High rate of motion of full scale MLV generates considerable electric charges on a surface of a body MLV by virtue of triboelectric effects, hindrances in the work of radioelectronic devices. Therefore engineering process of a management system should actuate an estimation of value of electrical fields on elements of designs of MLV, the possible ways of using of the induced electric power for feeding of an onboard electrical circuit, supposing that the set forth above problems are also constituent part of the developed system of monitoring and mission control of transportation facilities with a magnetic levitation.

From all set of problems in the present report we shall limit by representation of the base device of a management system of MLV - informational-control system, which should supply:

- Mission control of a platform of a transport means in speed range from zero point up to 140 m/sec;
- Measurement and transmission from onboard of MLV to a base control post of following parameters of a transport means motion:

- 1) A position of coils of platform concerning coils of travelling frame in its long direction (in a direction of traffic) with a definite discretization;

- 2) Position of platform of MLV concerning a path length;
- 3) Speed (instantaneous value) of moving of platform of MLV;
- 4) Acceleration (instantaneous value).

The informational-control system (fig.1) actuates a marcer-connected radio waveguide 1, arranged between transport rails of way structure on all its length. Along capline of generatrix of the waveguide the groups by encapsulated by dielectric of foramens 2,3,4 with a step $2t/6$, where t - reference size of travelling coils (fig. 2) are located. On the ends of waveguide the receivers of electromagnetic signals 5 are established. The outputs of receivers paired to inputs of the summator 6, and the output of last paired to an input of the decoder 7. From outputs of the decoder the signals on the channels of information go to digital-to-analog converters 8, with outputs of which the inputs of conversing, measuring and receiver recorders (9^I - registration of a vertical gap, 9^{II} - registration of transverse displacement, 9^{III} - registration of speed and 9^{IV} - registration of acceleration), control unit by feed of coils of travelling frame 10, by reversible meters 11 (ring-type and programmed) and devices of derivation (12^I - calculator of 1-st derivative (speed), 12^{II} - calculator of 2nd derivative (acceleration)) are paired. On the platform of MLV the generator of electromagnetic waves 13 with the radiator 14 is established. The radiation is modulated by informative signals about work of sensors of vertical gap 15, of sensors of transverse displacement 16, sensors of direction of traffic 19 with the help of the modulator 17 and coder 18.

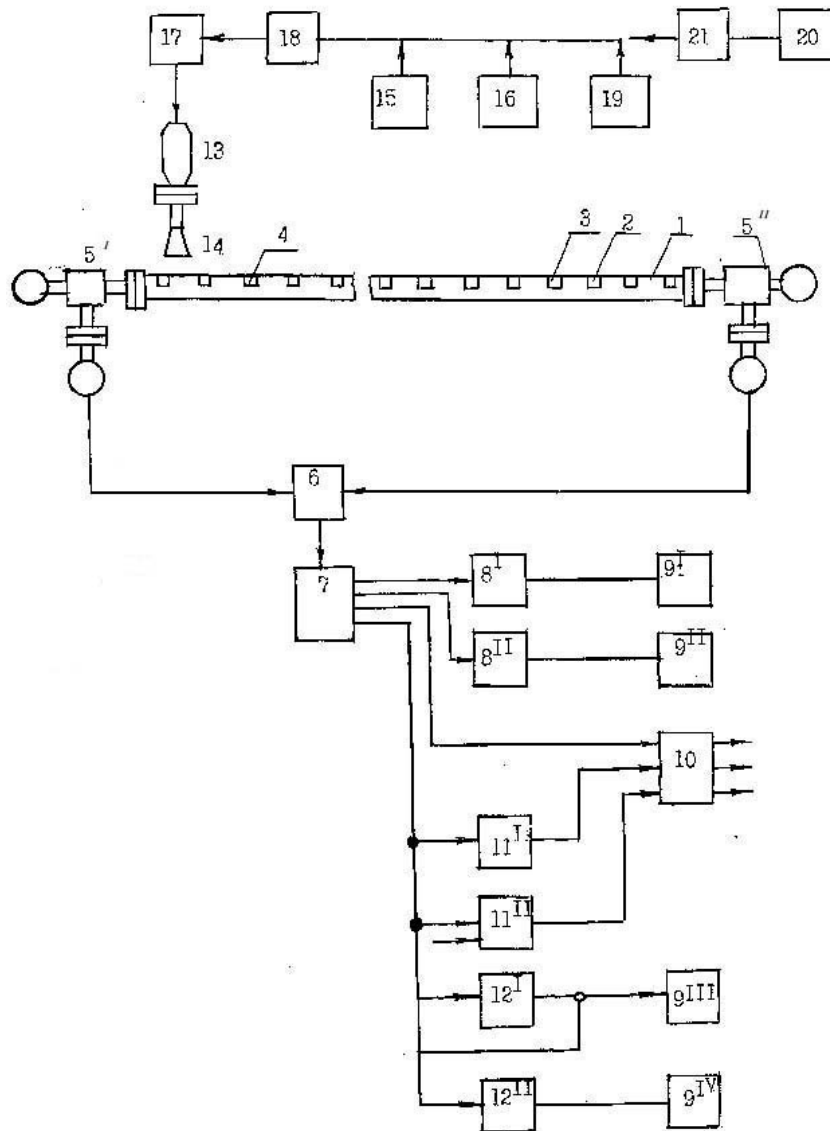


Fig. 1

In the initial moment of motion of MLV from any point of a route, the management by frequency of switching of coils of electromagnets on travelling frame implements from a base control post "manually" or by command of special sensor programmed on a definite mode of boost. At interception by the radiator 14 of the first in a current of traffic foramen of connection with the waveguide the signal of the generator, going through this foramen to a cavity of the waveguide, is diffused along the waveguide on two opposite directions to its ends, where registers by receivers 5. On an output of receivers supplied with video detectors, there are signals, the levels of which are proportional to spacing interval from an insertion point of a signal to a cavity of the waveguide up to receivers. In the summator 6 this signals are summed up in such a manner that on an output of the summator the signal levels remain constants on all of a travel line of MLV. The decoder 7 makes decoding and distribution the information of information signal on channels, then from each of sensors it goes on own channels to the conversing device 8, measuring-receiver recorder 9, meter 11 or differentiative device 12. The measuring-receiver recorders 9 measure and register on a technical information carrier the parameters of motion and attitude of MLV, mentioned above. Thus the control unit by a current of travelling frame 10, receiving signals at the moment of transit by the platform of MLV of marker foramens in the marker-connected waveguide, forms a command signal by a linear three-phase electromotor on each of three outputs of a control unit 10, interleaving signals of swinching on of phases A, B, C of coils feed on travelling frame. This queue is set by the reversible meter 11 of marker signals. The devices of derivation 12 provide calculus maiden and flexon on time of marker signals with the purpose of obtaining of instantaneous values of speed and acceleration of motion of platform of MLV.

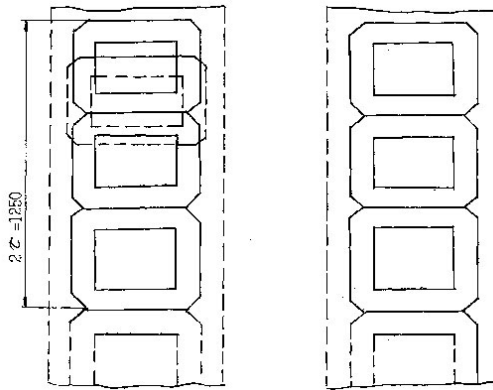


Fig. 2

The meter of marker signals 11 has some channels of the score: 1 - ring-type reversible meter on 2 and on 6 with a three-phase output; 2 - programmed reversible meter by capacitance 144 impulses.

The assigning of the first meter is described above. The programmed reversible meter is indispensable as the setting device of sections of a path, on which the definite modes of boost, motion, inhibition, veering of direction of motion of platform of MLV will be realized. Besides on a measuring - receiving recorders of base control post the information on operational mode of the power system of travelling frame goes: power supply voltage of coils of travelling frame, feed current, form of a current, intensity of magnetic field.

Feature of the linear synchronic engine is the necessity of regulation of power supply voltage of a winding on travelling frame for stringent conformity with a location of crew on a line and with speed of its motion. As only unguided magnets of excitation are located on board, that in figure 2 their projections are rotined a broken line, the speed control is possible only through the power supply system, which thus becomes a component of control-system by motion, which allows automatical switching-on and switching-off of sections at MLV moving along link [3]. It is a composite technical problem and in this direction the intensive researches are conducted. So, the Institute of Technical Researches of National Railways of Japan within the framework of a transport system with the magnetic suspension conducted initial studies of a number of management systems of activity of the linear synchronic engine [3], constructed on principles of location:

1 - the electromagnetic wave radiated by a fixed transmitter, is received on a mobile object, where it convertes to a wave of other frequency and is dispatched back; the acceleration and the mowing speed of object are determined on a transmitting station on a phase difference between radiated and adopted wave

and on speed of change of this phase difference, thus as the carrier of electromagnetic waves the open coaxial cable is used;

2 - the inductive method, in which the position of crew is determined discretely by inventory of number of interceptions of wires of a special two-wire line made along a path, thus the line feeds from the voltage of a high frequency, and the moment of transit of interception is determined on petering of induced signal in the antenna consolidated on a carriage rolling stock;

3 - location with the help of light signals modulated at motion of MLV with the help of fixed perforated or resilient light screens;

4 - the inductive system of location, in which as a working signal is used a difference of EMF, induced in the antenna by two way high frequency lines with symmetrically removed interceptions of wires and with the purpose of decreasing of a discreteness the system is designed as multiphase.

As each of the indicated methods is not absolutely reliable for a line, the implementators guess to use as the basic system - the system 4 with a redundant system such as 3.

It is uneasy to evaluate, that such overlapping of principles does not decide a put problem and essentially complicates a system of reduction of information received from primary sensors, besides the management system should be free from influencing interfering signals conditioned by aimings of feeding circuits and should reliably operate in conditions of a mist, dust content, gassed condition.

This problem is resolved by us at the expense of usage of microwave electromagnetic waves and as a means of channeling of electromagnetic waves - closed empty waveguide. At practical implementation of such approach with allowance for specificities of solved problems it was necessary to undertake measures, that the electromagnetic energy transferred through a provoked foramen of connection in the waveguide, was not reradiated through adjacent foramens of connection, and was routed to inverse ends of a wave-guide line, where the receivers are arranged.

Basically, as a wave-guide line it would be possible to use both waveguide of rectangular cross-section, and waveguide of round cross-section. But from the point of view of manufacturability and cost be more preferential is a circular guide (it may be the tube from any metal coated inside with a layer of metal with high electrical conductivity - cuprum, aluminium, argentum).

As is known, for a circular guide the main type of a wave is the wave such as H_{11} , and from structure of a field of this type of waves [4] follows, that the longitudinal slots in such waveguide are radiationless, and consequently the mentioned above condition of an radiationless in this case is executed. But by virtue of a principle of reciprocity through such longitudinal slot it is impossible to excite a wave of a type H_{11} , but it is possible to excite a wave of a type H_{01} . The escaping from such situation can be to excite an intermediate type of waves which is not main, but is capable on small length to be transformed to a wave H_{11} . Such type is the wave H_{01} . As the longitudinal slot lacerates electrical lines, and the magnetic lines «fail» in a slot, the excitation of a circular guide through a longitudinal slot under the indicated scheme is possible, if in a near-field region the frame of a field corresponds to type of a wave H_{10} - the main type of waves for the rectangular waveguide. That is, the excitation of a circular guide on the main type of a wave can be executed, using as the radiator the rectangular waveguide or rectangular horn. In a fig. 3 the investigated versions of excitation of a circular guide through a longitudinal slot are submitted: through a broad wall of the rectangular waveguide at orthogonal arrangement of waveguides (a), at coaxial arrangement of waveguides (b), from butt end of the waveguide (c). Technologically most reasonable the third version (fig. 3c) has come to light.

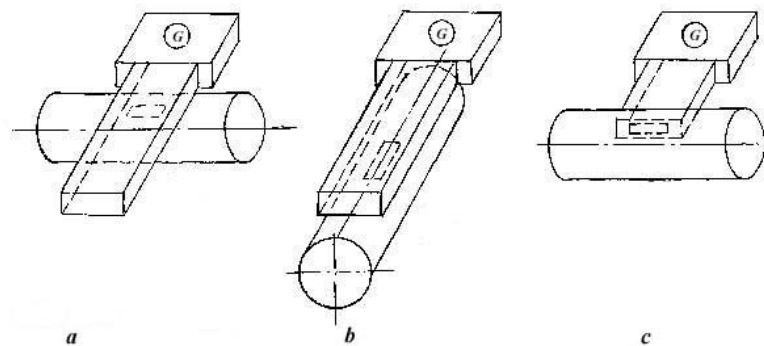


Fig. 3

Thus for an avoidance of excitation of higher types of waves it is necessary correctly to select not only operational frequency of radiation (above its critical value), but also to set the optimum size of a circular guide. That is it is necessary to construct the chart of vibration modes similar [4], with the help which one would manage to select such range of values of microfrequency, longitudinal and transversal sizes of the waveguide, in which the quantity of undesirable crossing and superimposed modes of vibration would be minimum. The speech goes that for a homogeneous transmitting line the connection between a critical wavelength λ_{cr} , wavelength in free space λ_0 and wavelength in a line λ_w is determined by a ratio

$$\left(\frac{2p}{I_0}\right)^2 = \left(\frac{2p}{I_{cr}}\right)^2 + \left(\frac{2p}{I_w}\right)^2.$$

At length of a line L quantity of half-waves will be equal $\frac{2L}{I_w}$. Then the given equation can be written to a view

Where D - diameter of the waveguide, k - radicals of a cylindrical functions, N - number of half-waves in a section L , c - speed of light. This equation in a graphic presentation is the chart of vibration modes. Having constructed the given chart (it here is not resulted because of its unwieldness) it is possible to select the areas, where the superposition of undesirable modes is eliminated or is reduced to minimum. For the « lengthy » waveguide, when attitude of diameter of the waveguide D to its length is small, the value of ordinate on the chart $\left(\frac{fD}{100}\right)^2 = 14$. At diameter of the waveguide $D = 3,2$ cm, the value of an operational frequency of an electromagnetic field is equal 12,21 GHz. Concomitant to a type H_{01} the vibration mode E_{11} can not be excited because of unfavorable orientation of a slot of connection for this type[5].

These numerical data were utilised at designing of model of the marcer-connective waveguide which was utilised at realization of experimental researches. As a wave-guide line the aluminium tube a dia $D = 3,2$ cm, length $L = 400$ cm utilised, in which e along generatrix the rectangular slots were cut, the size of which was determined, outgoing from electrodynamic reasons [5]. Spacing interval between slots $l = 2t/3 = 416,6$ mm, where $2t = 1250$ mm, fig. 2.

The high-stable generator.

As a source of electromagnetic oscillationss the high-stable generator of 3-cm of range with reference thermo - stable (from invar) circular cavity utilised, live under the scheme of the band-elimination filter [6]. On frequency 12,2 GHz the level of a transmitting power was about 80 mW, the frequency instability did not exceed 10^6 in temperature range -30... +30 °C.

With the help of a measuring set permitting serial excitation of slots of connection and measurement of power, connection reradiated from adjacent slots, the losses of microwave-power on reradiation from passive (that is, located outside of an exposure zone) foramens of connection, reallocating of microwave - power on receivers \mathcal{S} and \mathcal{S}^{II} (fig. 1) were determined at moving of the radiator along the waveguide (fig.4a, , where factor $k = 10 \lg P_1 / P_0$, P_0 - power on a fissile slot of connection, P_1 - power on a passive slot of connection, N - sequence number of a slot of connection; and fig.4b, where P_1 (xxx)- power in the receiver \mathcal{S} , P_0 (ooo) - power in the receiver \mathcal{S}^{II} , N - sequence number of a slot),

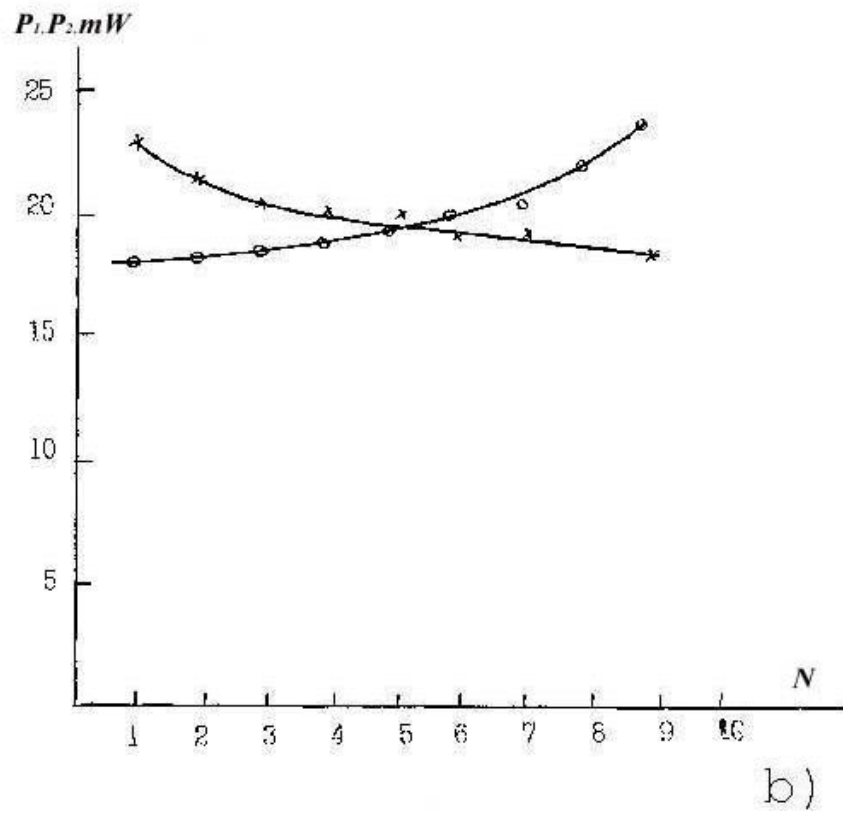
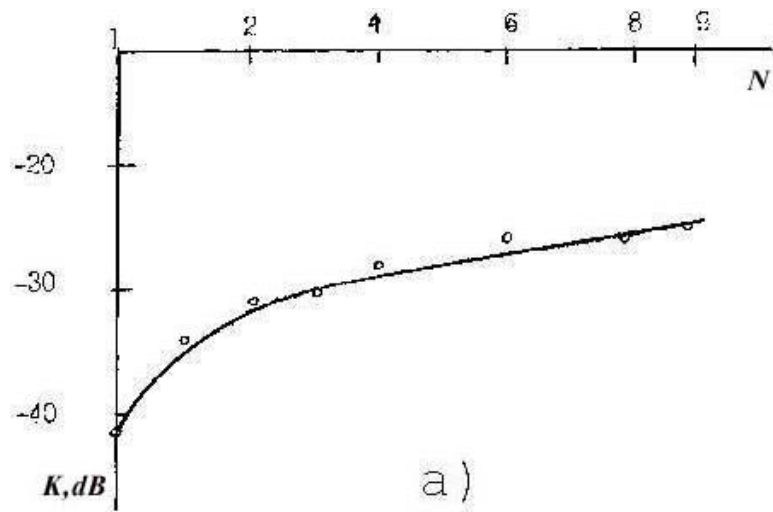


Fig. 4

efficiency of transformation of a surge H_{10} into H_{01} (and then in H_{11}), depending on a angle of excitation (fig. 5), slot-hole foramen, describing mutual orientation, and beaming rectangular waveguide.

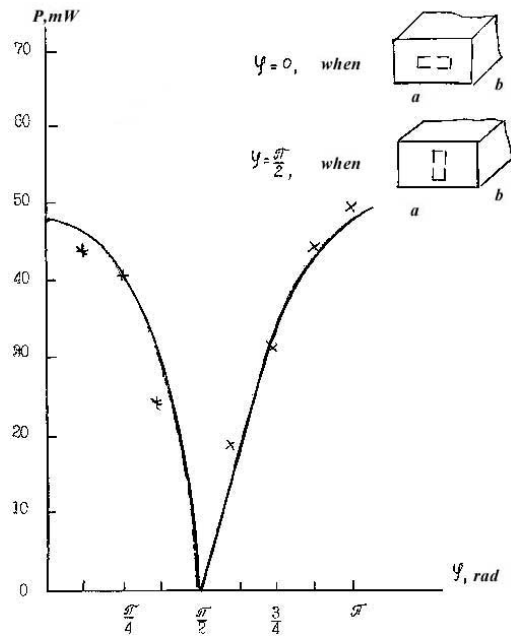


Fig. 5

In a fig. 6 the general view of the generator, where 1 - generating diode (gunn diode), 2 - low-pass filter (for submission of a supply voltage), 3 - mounting point of the diode, 4 - reference (stabilizing) resonator on a surge such as H_{011} , 5 - tuning posts, 6 - matched load is shown.

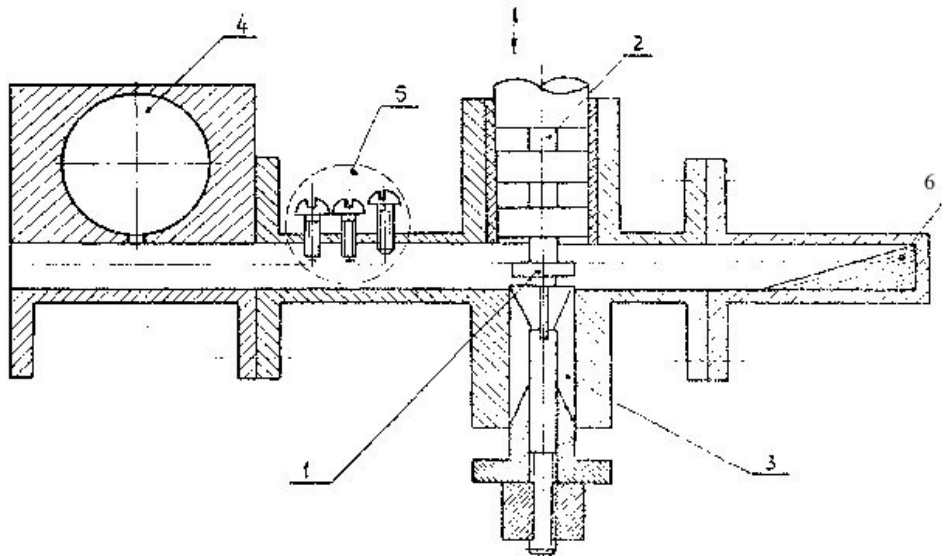


Fig. 6

From submitted experimental data it is visible, that the offered concept of the marcer-connective waveguide for construction of an informational - control management system for transportation facilities with a magnetic levitation is productive, and with its help it is possible to decide problems at least of exploratory nature. Having decided some technological problems (having ensured a galvanic isolation between the waveguide and receiver, using highly sensitive and energy-strong receivers), the expansion of a wave-guide line can be made rather by considerable. The estimations demonstrate, that at usage of sources of microwave-radiation with output power 80 mW on frequencies in range 10-12 GHz and receivers with sensitivity of 10-11 W permissible length of a wave-guide line makes 1 km. Usage of

travelling amplifiers set along a line decides an actual problem of construction of an informational - control system basing on radiowave methods.

The trace amplifier.

At propagation of an electromagnetic wave on the main marcer-connective waveguide the losses of a surge are foregone both at the expense of losses in walls of the waveguide, and at the expense of losses of type conversion of surges and at the expense of radiation of a part of energy from longitudinal slots in the main waveguide. The value of losses is uneasy for evaluating by a computational way, and also with large accuracy to meter instrumentally. It allows to demand to parameters of tract (or trace, line) microwaves - amplifiers, to determine periodicity of their arrangement along the main waveguide.

Naturally, that the minings of a perspective type of transport, what are magnitolevitative transportation facilities, should base on modern radio electronic base and allow for the tendencies of development of the conforming radio electronic components.

Outgoing from a previous experience in mining functional devices on the basis of volumetric semiconductors with negative differential resistance [1,2], the amplifier of a type the modulator-demodulator was selected from quality of traveling amplifiers. The essence of this engineering solution is visible from a fig. 7.

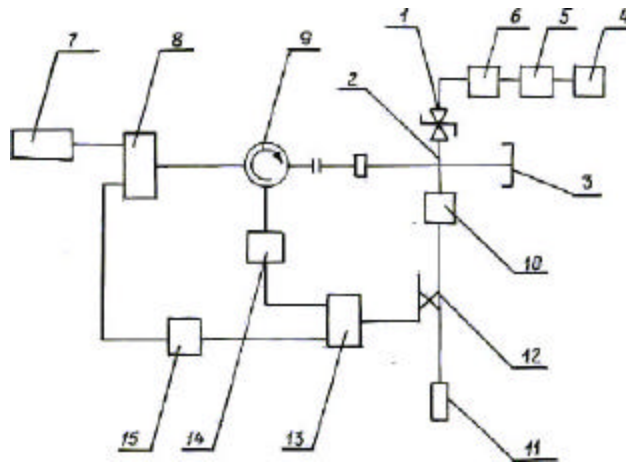


Fig. 7

The semiconducting diode frame 1 in a ceramic body is placed in a superhigh frequency resonator 2, derivated by a section of the waveguide with the short-circuit cylinder piston 3. Power supply voltage from a source 4 moves on the diode through a decoupling choke 5 and low-pass filter 6. By an input very high frequency a signal by frequency ω_n , modelled by a source 7, through the summarizing device 8 and the circulator 9 acts(goes) on diode frame 1, which one generates a signal on a resonator frequency ω_r . At the expense of nonlinearity of semiconducting diode frame on a IF circuit 10 the signal of an intercarrier frequency $\omega_{if} = \omega_s - \omega_g$ (an autodine mode) develops, which one goes on load 11 and can be informative, for example to testify to serviceability of a segment of the main waveguide and signal source, feading the marcer-connective waveguide. The part of a signal of an intermediate frequency through a directional coupler 12 goes on a signal input of a parametric converter 13, to the second input(entrance) which one through the phase change 14 the second arm of a ferrite circulator is connected. The output arm of the parametric up-converter through a system disfiltering 15 is connected to the summarizing device, hooked up to the maiden arm of a circulator. It is uneasy to show, that at submission on the parametric up-converter, the capacitance of a varicap in which one under effect of a signal ω_r changes under the law $C(t) = C_1 \sin(\omega_r t)$, signal of an intermediate frequency $U_{if} = U_1 \cos(\omega_{if} + j)$, voltage on a combination frequency $\omega_s = \omega_g + \omega_{if}$

$$U_2 = \frac{1}{2} \mathbf{w}_s U R_L \cos(\mathbf{w}_s t + \mathbf{j})$$

(here R_L - resistance of load for frequency \mathbf{w}_s , C_1 - the amplitude of change of capacitance) is in a phase with an input signal \mathbf{w}_{if} , and accessory voltage in a signal contour

$$U_3 = -\frac{1}{4} C_{w1}^2 U_{if} R_L \mathbf{w}_s \mathbf{w}_{if} R_{if} \cos(\mathbf{w}_{if} t + \mathbf{j})$$

is precisely in phase opposition with an input signal. The regulation of the phase change 15 provides maximum rating of a gain. The ratio Manly-Rou ad-hoc can be shown by the way:

$$\frac{P_g}{\mathbf{w}_g} + \frac{P_s}{\mathbf{w}_s} = 0; \quad (1.1)$$

$$\frac{P_{if}}{\mathbf{w}_{if}} - \frac{P_s}{\mathbf{w}_s} = 0; \quad (1.2)$$

where P_{if}, P_g, P_s - power on a signal frequency \mathbf{w}_{if} , pumping frequency \mathbf{w}_g and converted frequency \mathbf{w}_c , accordingly. At positive value P_g the equation (1.1) is contented (fitted) at negative power P_s . Accordingly equation (1.2) is contented at positive value of power on an intermediate frequency. It means, that the power on a IF "is consumed" by a varicap of a parametric converter modulated signal of pumping, and on the summarizing device the power on frequency \mathbf{w}_s of an input signal, reinforced in $\mathbf{w}_g / \mathbf{w}_{if}$ times. The maximum amplification is reached at the conforming phase relations between signals on frequencies \mathbf{w}_g and \mathbf{w}_{if} , achievable by regulation of the phaseshifter 15. The selection of frequencies in the ratio $\mathbf{w}_s > \mathbf{w}_g$ provides:

- a) Stability (immunity) of operation of the device;
- b) A sharp response, as the floor of a noise is introduced on the part of a parametric converter (small "noise" of a signal);
- c) Functionability of the device at spurious changes (within the limits of passband of a parametric converter), as the drifts of frequency \mathbf{w}_g will entail the same drifts \mathbf{w}_{if} , and as a result of boosting transformation in the parametric device the frequency \mathbf{w}_s remain invariable. At diverse ratio \mathbf{w}_s and \mathbf{w}_g ($\mathbf{w}_s < \mathbf{w}_g$) positions "a" - "b" are defaulted.

The summarizing device can be realised on hybrid rings with the conforming phase balancing of arms, on quadrature or slot-hole bridges. Taê as the usable sensitivity of the reviewed device only on some decibel is lower than sensitivity of superheterodyne converters with an external local oscillator (this property of all generating converters), and the power generated by semiconducting diode frame (gunn diode), makes tens and hundreds milliwatt, at interplay in a parametric converter input and generated of signals the considerable gains receive. Therefore, the efficiency of generating converters can essentially be increased, in conventional constructions which one the supressing part of power, generated by the Gunn-diode, is dispersed in ferrite isolators which are switched on in a stop direction, that creates padding circuit noises of a signal. Such scheme of the generating converter is expedient the IF differs and from operational mode with usage for the subsequent amplification of multistage amplifiers.

The designed amplifier for compensation of losses in the main marcer-connective waveguide [3] has properties, relevant with allowance for of solved problems:

- 1) the component of a very high frequency of an input signal of the device augments a linear segment of a transmission factor at preservation of a usable sensitivity (see fig. 8, where the transmission characteristic of the given device, curve 1 is adduced; a curve 2 - for canonical autoline mode;

$$\frac{\mathbf{w}_g}{2p} = 9440 \text{ MHz}, \quad \frac{\mathbf{w}_{if}}{2p} = 60 \text{ MHz};$$

- 2) at usage of an information signal on an intermediate frequency the necessity for a multistage IF-amplifier passes and the power inputs, bound with a feed of these amplifiers are reduced;
- 3) the thermal noises conditioned by heating of members of a microwave channel by an exuberant microwave power decrease;

4) The general noise factor also is reduced, as the noise factor for parametric converters is much less, than for IF -amplifiers.

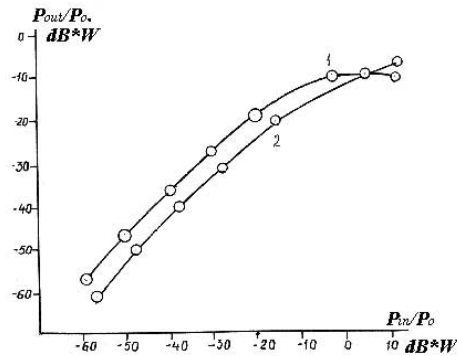


Fig. 8

From the transmission characteristic also it is visible, that in the given amplifier is augmented on 5-6 dB a transmission factor and are increased a linearity of the transmission characteristic on a segment of small levels of input signals and usable sensitivity of the device as contrasted to autodyne converter, constructed on the canonical scheme. So substantial improvement of parameters of the designed amplifier as compensator of losses of microwave-energy in the main marker-connective waveguide with allowance for of high power strength allows to consider, that the indicated amplifier can be reviewed as working version by selection of a finalized version of the traveling amplifier.

Receivers for a radiowave management system and control

The second base submachine of a radiowave management system is the receiver of electromagnetic waves. The electric power installation of a transport means is a potent source of electromagnetic waves in different segments of radio-frequency range. Therefore usage of traditional receivers on p-n-junction (superheterodyne) is inconvenient at least on two causes: 1 - the strong electromagnetic field is a source of potent interfering signals, and the filtration of these interferences is composite and expensive measure; 2 - the potent interfering signals can damage input circuits of the receiver. Looking up of paths of construction energy-protected, whenever possible selective, receivers high- μ therefore is indispensable.

The a priori indicated requirements can be satisfied with receivers on generating Gunn-diodes [7]. Initial sendings for realization of such researches is that in generating modes the Gunn-diodes are characterized by considerable nonlinearity both fissile, and jet resistance. The modulation of capacitive reactance of the diode at the expense of periodicity of a germinating and petering of domains of a strong electrical field was earlier utilised for a parametric control by a signal on half in relation to Gunn-oscillation's frequency as with external pumping, and without it, when the signal source of pumping was served by Gunn-oscillations. The modulation of fissile resistance was applied for "conversion downwards" of microwave signals of a small level. Certainly, such separation of modes largely conditionally, as in the diode descends simultaneous modulation both fissile, and jet resistance. The primary development of nonlinearity of a pure resistance depends on a mode of the Gunn-diode. Analysis of operational modes of diodes in a mode of the reshaped domain [8] has allowed to construct the constitution diagram of domains of a strong field in frequency function of generating, of a profile of doping and kinetic characteristics of a semiconducting stuff and to show, that more steep modulation of reactance conditioned by a resizing of domains and a phase difference between a HF-current and a HF-voltage is characteristic for modes with more high scale of formation of domains. The large measure of nonlinearity of a pure resistance is characteristic for modes with less developed domains. Therefore depending on put practical problems it is possible to use nonlinearity either volt-farad, or volt-ampere characteristic of Gunn-diodes, it is teleologically applying diodes with optimum for each of problems by a kind of the characteristic.

In a fig. 9 the skeleton diagram of the amplifier in the greatest measure operating a diversification of properties of Gunn-diodes the Gunn-diode 1 is figured, bound with a radial resonator 2 is placed in a section of the waveguide 3 with the short-circuit cylinder piston 4, serving for the coordination of the diode with an input signal. The input signal from a source 5 through a three-input circulator 6 and bandpass filter 7 goes on the Gunn-diode, where at the expense of nonlinearity last is admixed with a signal generated diode. The signal which is growing out of mixing (by a signal of an intercarrier

frequency), is excited on a contour a IF 8 (L_1, C_1), to which one the IF-amplifier 9 through a coupling coil L_2 , inductively connected with L_1 .

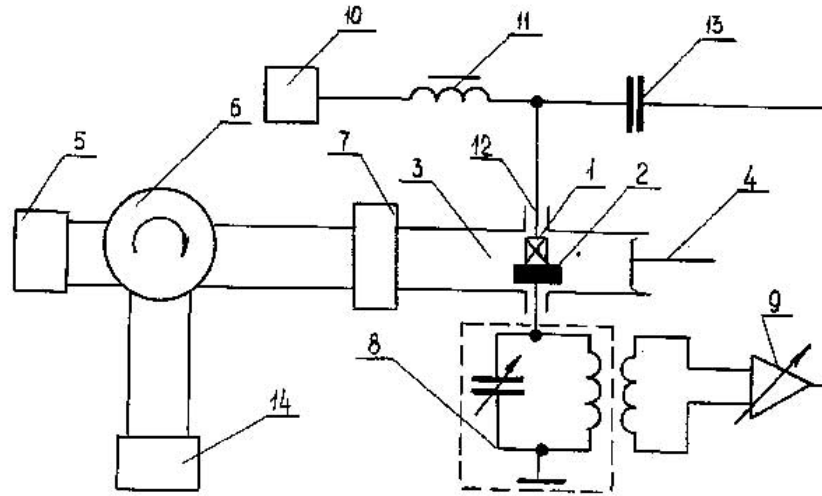


Fig. 9

The Gunn-diode is connected to the power source 10 through the throttle 11 and low-pass filter 12 with frequency of a cut-off above than value of a IF. The voltage from a IF-amplifier through separating capacitance 13 acts on the Gunn-diode through input of a supply voltage. By an output very high frequency the signal acts on load 14.

If frequency ω_c of an input signal and frequency ω_g of a signal generated by the Gunn-diode, are connected by a ratio $\omega_g \pm \Omega = \omega_s$, where Ω - intermediate frequency, on which one the contour 8 and amplifier 9 is customized, at the expense of modulation of the Gunn-diode by voltage of frequency Ω radiation spectrum of the diode will be contained component ω_s , on amplitude considerably superior an input signal from a source 5. For a symmetrical zone of generating of the Gunn-diode (that is for dependance of a level of output power to power supply) by supply on the diode of voltage of an intermediate frequency $U'_{if} \cos \Omega t$, the power of a generated signal will change under the law:

$$P(t, M) = \frac{P_0(1 - M \cos 2\Omega t)}{1 + M},$$

where $M = M(U'_{if}) = \Delta P_m / P_0$ - factor of an amplitude modulation on power; P_0 - maximum rating of power; ΔP_m - deviation of power from an average level up to maximum; U'_{if} - amplitude of modulating voltage.

The amplitude of a generated signal is determined as

$$E(t, M) = g\sqrt{P(t, M)} = E_{0r}\sqrt{\frac{1 - M \cos 2\Omega t}{1 + M}} \approx \frac{E_{0r}}{\sqrt{1 + M}}[a_0(M) + a_1(M) \cos 2\Omega t],$$

where $E_{0r} = g\sqrt{P_0}$ - signal amplitude in absence of modulation; g^2 - aspect ratio between power and square of field intensity in a used resonator [9]; $a_0(M)$, $a_1(M)$ - decomposition values.

Thus there is as well a frequency modulation. For a case of a sweep-frequency modulation the signal is generated

$$e_r(t, M) = \frac{E_{0r}}{\sqrt{1 + M}}[a_0(M) + a_1(M) \cos 2\Omega t] \sin(\omega_r t) - m \sin \Omega t$$

where $m = m(U_{if}) = \frac{\Delta \mathbf{w}_r}{\Omega}$ - index of frequency modulation; $|\Delta \mathbf{w}_r| = S_0 U'_{if}$; S_0 - steepness of a voltage tuning.

Using known ratio from a function theory of a Bessel

$$\sin(x \sin \Theta) = 2 \sum_{n=0}^{\infty} J_{2n+1}(x) \sin(2n+1)\Theta;$$

$$\cos(x \sin \Theta) = J_0(x) + 2 \sum_{n=1}^{\infty} J_{2n}(x) \cos 2n\Theta$$

For a radiation spectrum Gunn-diode, we receive expression

$$\begin{aligned} e_r(t, M) = & \frac{E_{0r}}{\sqrt{1+M}} \{ [a_0(M)J_0(m) + a_1(M)]J_2(m) \sin \mathbf{w}_r t + \\ & a_0(M)J_1(m) - \frac{a_1(M)}{2} [J_1(m) - J_3(m)] \sin(\mathbf{w}_r \pm \Omega)t + \\ & a_0(M)J_2(m) + \frac{a_1(M)}{2} [J_0(m) + J_1(m)] \sin(\mathbf{w}_r \pm 2\Omega)t \} \end{aligned}$$

Thus, the radiation spectrum at the indicated type of modulation consists of a carrier frequency \mathbf{w}_g ($n = 0$) with amplitude $E_{0r}J_0$ and side frequencies $\mathbf{w}_g \pm n\Omega$ with amplitudes $E_{0r}J_1(m), E_{0r}J_2(m), \dots, E_{0r}J_n(m)$, where $J_0, J_1, J_2, \dots, J_n$ - cylindrical (Bessel) functions 0, 1, 2, ..., n-rate from argument m ; E_{0r} - maximum rating of the modulated voltage. A gain of the device is the relation of voltage on the maiden side frequency of a modulation spectrum, equal frequency of an input signal, to an input signal at a transmission factor of the bandpass filter \mathbf{b} on this frequency

$$?_G = \mathbf{b} E_{0r} \frac{\{ a_0(M)J_1(m) - \frac{a_1(M)}{2} [J_1(m) - J_2(m)] \}}{\sqrt{1+M}}.$$

As the transmission factor of the Gunn-diode is peer a mode of the generating converter to relation of power on an intermediate frequency to power of an input signal:

$$?_{if} = \frac{?_{if}}{?_s} = \frac{4g_L g_{Lif}}{(g_{if} + g_{Lif})} \cdot \frac{g_1^2}{(g_0 + g_L)^2}$$

(here g_L and g_{Lif} a IF-load admittance on a very high frequency and intermediate frequency accordingly; g_{if} , g_0 and g_1 - conductivity of the Gunn-diode on an intermediate frequency, direct current and on a first harmonic), the voltage on an amplifier output of an intermediate frequency with a gain K_{if} will be determined by expression:

$$U'_{if} = \frac{2e_r g_L g_1}{(g_{if} + g_{Lif})(g_0 + g_L)}.$$

From here it is clear, that the amplitude of a first harmonic in a side band, that is output amplitude, is a function of a bias both input amplitudes and signal of an intermediate frequency. By available regulations it is possible to achieve optimum distribution of power in a spectrum of a converted signal with the purpose of obtaining a maximum gain.

At voltage on the diode consisting of constant voltage 8,5 V and voltage of an intermediate frequency $U'_{if} \cos \Omega t$, the modulation of frequency (fig. 10, c) and power (fig. 10, d) implements. As it is visible, the curve A of dependence $P_g = f(U_0)$ is close to selected in the idealized analysis.

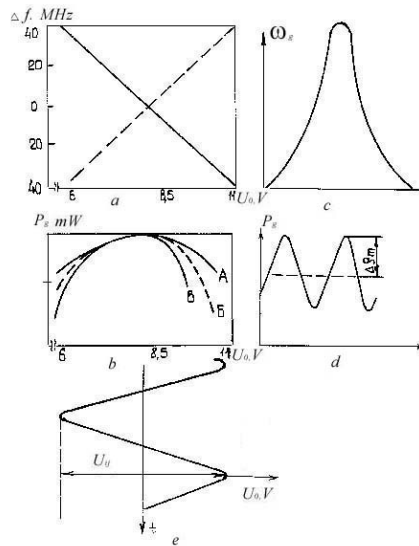


Fig. 10

Having taken advantage the computed values of conductivity of diodes within the limits of model of reshaped domains and value of product of concentration of carriers on length of an active area of used diodes $n_{0L} = 2 \times 10^{12} \text{ cm}^{-2}$ at $\Omega = 10 \text{ MHz}$ and $m = 8$, we shall receive relation of a voltage amplification factor to a level of an input signal at three values of a factor of an amplitude modulation on power (fig. 11).

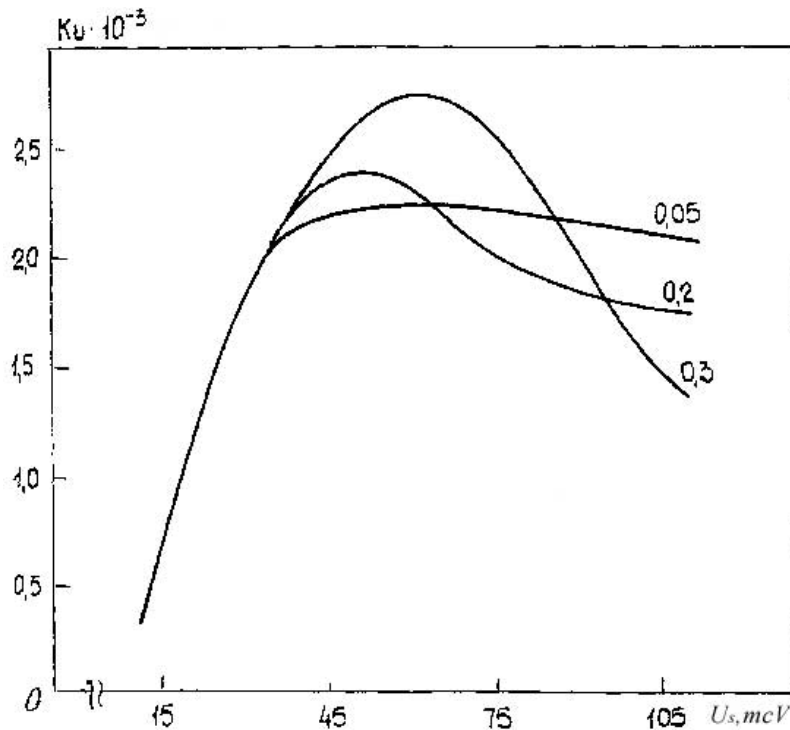


Fig. 11

In experiment for the diode with selected relation $\Delta w_g = f(U_0)$ and $P_g = f(U_0)$, as in a fig. 10 (for the diode A), the relation of a gain to a level of an input power is obtained on frequency 9,4 GHz at a band of amplification of an intermediate frequency 5 MHz and transmission factor of the bandpass filter 0,9 (fig. 12).

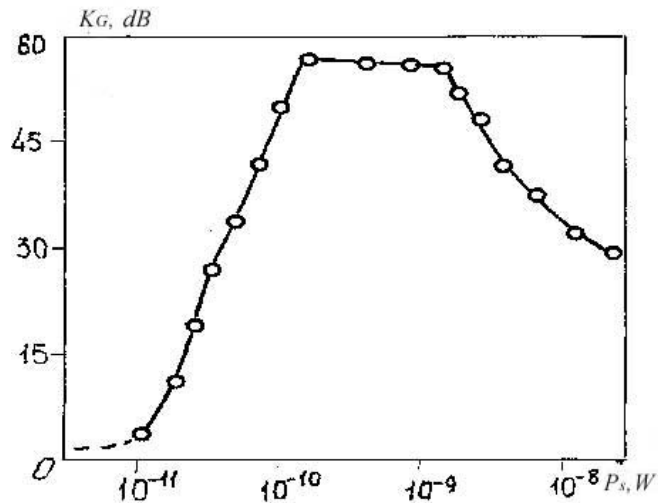


Fig. 12

As it is visible, values of a gain and the usable sensitivities of the reviewed receiving-amplifying device essentially surpass achievable values of these parameters both for stable amplifiers, and for regenerative and are characterized by sensitivity, close to sensitivity of superheterodyne receivers, with output frequency, equal input, but transferred on a high level oscillation of the Gunn-diode, provide $K_G \cong 60$ dB and more in a band in some megahertz. At spurious frequency drifts of the Gunn-diode w_g on Δw_g within the limits of amplifier bandwidth of an intermediate frequency the spectrum of a combinative signal is moved, and after modulation on an output the value w_0 is restored. The stabilization of the characteristics of the device as unit at the expense of depositing minimum number of padding members considerable more effectively as contrasted to by righting system on clusters, efficiency which one can be increased by actuation of contours of selftuning of frequency and power of the diode or high-Q, including thermo - indemnified, tightening resonators.

Thus, the reviewed receiving-amplifying devices are almost ideal receivers for a radiowave informational-control system.

Devices for definition of attitude of a transport means.

At a carrying out of tests both the range model, and full scale transport means with a magnetic levitation the relevant informative parameters are the spacing intervals between MLV and travelling frame (horizontal plane) and between MLV and lateral guides, i.e. the information on attitude MLV is indispensable. In view of relevance of such information for a management system of MLV [10] it is extremely necessary, that the reliability of the conforming instrumentation was high. If to take into account, that the indicated instrumentation should work in conditions of strong electromagnetic fields created by the drive MLV, becomes clear, that the conforming hardware constructions should form on components with high energy-firm properties and operate on frequencies as much as possible removed from radiated frequencies, created by the drive of MLV. Thus it is important, that the information signal had large amplitude, in the sense that it should essentially surpass on amplitude interfering signals on information frequencies.

The analysis of the engineering solutions satisfying to the mentioned above requirements, demonstrates, that in the greatest measure to these requirements fit functional devices on the basis of semiconducting structures with volumetric negative differential conductivity in superhigh frequency band [7]. Using a diversity of physical phenomena in such structures, it is possible to create functional devices realising a lot of radio functions, including the decision of problems of the control of movings of objects, the measurement of their geometrical sizes etc.

For these purposes was designed *self-pumping meter of deviations of spacing interval* between MLV and trace structure. The operation of the designed device is based on a phenomenon of pulling of frequency of a semiconducting microwave autogenerator by unmatched microwave load, as which the travelling frame acts, and device is established on a body of MLV. Thus the drifts of frequency of generation called by changes of spacing interval between MLV and particulateing reflect travelling frame, are informative. The information signal is excreted on a contour of low frequency and is a product of mixing of frequency of autogenerator, the radiation of which interacts with travelling frame, and of frequency of the second microwave - generator unloosened with the maiden autogenerator with the help of the conforming valve devices.

In a fig. 13 the functional diagram of the device is submitted. The semiconductive diode 1, located in a two-input microwawe generator 2, is connected to the power source 3 through a low-pass filter 4. To the power source 3 through a low-pass filter 5 the semiconductive diode 6 is connected also. This diode is connected to a high-stable microwawe generator 7, which through a valve 8 and the controlled attenuator 9 is connected to the second input of a two-input microwawe generator 2, the maiden input of which through the phase shifter 10 is connected to the directional radiator (antenna) 11, directional on reflecting object I - II. Between the power source 3 and indicator 12 with the help of separating capacitors 13 and 14 the contour of low frequency 15, derivated by inductivity 16, resistor 17 and capacitor 18 is included. The radiator 11 is made fs pyramid-shaped horn with a ratio of the parties 1,23 - 1,25, that provides maximum reception of reflected from controled object I - II microwawe signal. Two-input microwawe generator is made pursuant to [11], the high-stable one-input generator is similar introduced in [12].

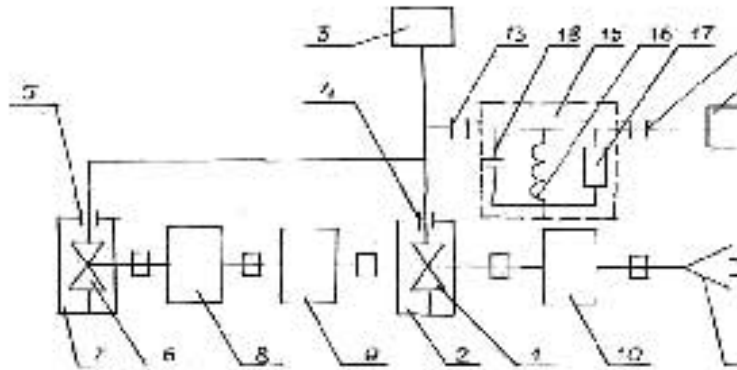


Fig. 13

The device works as follows. At receipting of rated voltage from the power source 3 on semiconducting generating diodes 1 and 6, two-input microwawe generator 2 and high-stable microwawe generator 7 generate microwawe signals by frequency ω_0 and ω_g accordingly, thus a signal with frequency ω_0 through the phase shifter 10 and the directional radiator 11 goes to a reference reflecting plane - on active travelling frame of MLV, which is the high frequency load of a two-input microwawe generator 2, and owing to effect of "frequency pulling" the change of spacing interval between devices and reflecting plane results in change of generated frequency by a two-input microwawe generator.

Following [13], we shall record a stability condition of a auto-oscillating mode of the generator:

$$\frac{g + jb}{G_L \omega_0} = j \left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right) + \frac{1}{Q_o} + \frac{G_L + jB_L}{Q_{out}}$$

where ω_0 , ω , Q_o , Q_{out} - resonant and current frequency, own and external Q-factor of a resonator, g, b - active and reactive components of conductivity of a generating semiconductive diode, G_L , B_L - components of load admittance. Pursuant to [14], the expression for current value normalized to a wave admittance generally can be written:

$$y_l = \frac{1 - r_L (e - j \frac{2\omega}{c}) [l + u(t - t_0)]}{1 + r_L (e - j \frac{2\omega}{c}) [l + u(t - t_0)]}$$

where l - spacing interval between semiconductive diode 1 and initial position of a reference plane ($t = t_0$), $c = 3 \cdot 10^{10}$ cm/sec, ρ_R - reflection coefficient of wave from a reference reflecting plane of controlled object. Deciding jointly equations (1) and (2), at $Q_0 \gg Q_{out}$, $|\rho_R| \ll 1$ (that is close to an actual situation) with

usage of an equation of the Euler, $e^{i\varphi} = \cos \varphi + i \sin \varphi$, it is uneasy to receive analytical expressions connecting drifts of frequency and current through the generating diode at variations of position of load:

$$\frac{\Delta w}{w'_0} \approx \frac{w - w'_0}{w'_0} = \frac{|r_L| |\sin j|}{Q_{out}},$$

where $\varphi = \arg \rho_R - 2\omega/c [l + v(t-t_0)]$, $\arg \rho_R$ - argument of a reflection coefficient.

At invariable value of a module of a reflection coefficient of active travelling frame, i.e. $|\rho_R| = \text{const}$, and at changing of spacing interval between the sensor and travelling frame, the frequency generated by a two-input semiconductive signal generator is a function phase distance between MLV and trace structure.

According to a functional diagram on a semiconductive diode 1 through a valve 8 and the controlled attenuator 9 goes a signal ω_0 generated by a high-stable microwave generator 7, so that as a result of mixing on the diode 1 of signals with frequencies $\omega'_0(\varphi)$ and ω_g , on a contour of low frequency 15 out a signal of an intercarrier frequency $\omega_R(\varphi) = [\omega'_0(\varphi) - \omega_g]$ is picks, the numerical value of which is a function of phase spacing interval φ between the diode 1 and reference reflecting plane of controlled object I - II through a periodic function $\sin \varphi$, the steepness of which is max at $\varphi = n\pi/2$, where $n = 0, 1, 2, \dots$. For maintenance of a sharp response of the device, i.e. obtaining of maximum frequency drifts $\omega_R(\varphi)$, being informative, at small changes l - the spacing interval between the diode and reference reflecting plane of controlled object, phase shifter 10 establish the conforming initial values of phase spacing interval between the device and reference plane.

For that the drifts of frequency of two-input microwave generator 2 reliably watched changes of spacing interval between mobile objects, i.e. for maintenance of reliable operation of the device, it is necessary to avoid a phenomenon of a genlocking, i.e. it is necessary the fulfilment of a condition, that

$$\sqrt{P_1/P_2} \geq \frac{w_L(j)}{w_0(j)} Q_{out},$$

where P_1, P_2 - the strengths of signal generated by a two-input microwave

generator 2, and of signal going to the diode 1 from a high-stable microwave generator 7. The conforming to this conditions the level of signal from a high-stable microwave generator 7, going to the diode 1, is regulated by a variable attenuator 9, and the valve 8 prevents hit of a signal from the two-input generator 2 in the high-stable microwave - generator 7 and provides due it the stability of its work. As both microwave generators 2 and 7 are fed from the common power source 3, the drifts of voltage of the power source will give approximately equal drifts of frequencies ω'_0 and ω_g , so that frequency rates $\omega_R(\varphi)$ at invariable values $|\rho_R|$ will depend only on phase spacing interval between the device and controlled object, i.e. the precise measurement of spacing intervals between mobile objects and small changes of these spacing intervals is possible.

As the low frequency contour 15 is connected to the generating diode 1, basically in this contour originating of self-oscillations is possible. To prevent excitation of self-oscillations in this contour at the expense of external negative conductivity of the diode, the values of parameters of the diode and

indicated contour should fit to a ratio $1/R_k < g < R_k/\rho_k^2$, where ρ_k - wave (characteristic) resistance of a contour, R_k - its ohmic resistance, $|g|$ - negative conductivity of the generating diode.

An adjustment of the device execute as follows. Establish some reasonable (from the point of view of the available indicator) the value of an differential frequency $\omega_R(\varphi)$ at normalized (initial) spacing interval between the device and object, by regulation of the phase shifter 10 provide that position of its control, at which the minimum changes of a graduation of the phase shifter provide a maximum frequency drift at the change of spacing interval.

The information on moving of object can be transferred on a radio channel and by indicator can be served a frequency meter or conventional amplitude-frequency converter translating changes of a differential frequency $\omega_R(\varphi)$ into voltage variations, which then are used of an information signal in a management system of MLV [15,16].

Sensors of a magnetic field between a transport means and fissile travelling frame .

At a management development of transportation facilities with a magnetic levitation (MLV), at tests of range models indicated MLV there is a problem of runtime check of value of a magnetic field in a gap between MLV and fissile travelling frame. Thus it is important, that the conforming meter of magnetic fields was inertialess, and the information on value of a magnetic field and its variations could be transferred on an off-wire channel. Allowing, that the operation of transportation facilities with a magnetic levitation is integrated to originating in their neighborhood considerable on intensity of interfering signals, it is necessary, that the indicated information signals were high-peak and are as much as possible removed on frequency from interfering signals, and meters were energy-strong enough.

To the largely indicated requirements fit auto generating meters of magnetic fields of microwave range. A practical problem of such research is the elaborating of a wide-range autogenerator with magnetic rearrangement satisfying at least to two conditions: maiden - that the generated signal was linearly connected to value of a magnetic field; second - that the output power, generated by autogenerator, was maximum in range of rearrangement within the limits of power capabilities of a fissile member of autogenerator and with minimum deviation (irregularity) of output power in frequency band in order to prevent amplitude-frequency conversion, which one can distort observed datas of the characteristics of magnetic fields.

The phenomenon of a ferromagnetic resonance of spherical resonators from an iron - yttrium granatum (IYG), used in quality of magnetoregulated contour in microwave generators, utilised for the remote off-wire control of value of a magnetic field in a gap between MLV and active travelling frame.

With usage of an theory of electrical circuits the analysis of the radio circuit keeping an sphere IYG in crossed closed loops and semiconducting packageless devices on Gunn-effect was conducted (fig.14 a, b).

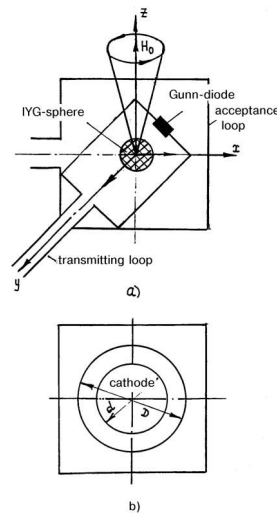


Fig. 14

With allowance for distributions of high frequency electrical and magnetic fields in semiconductor devices last are submitted by the way of terminating loads of a radial tl (transmit-line), and equivalent scheme of a ferrite sphere - es electrical pseudo-steady circuit constructed outgoing from mathematical analogy between equations, depicting a ferromagnetic resonance in a magnetized sphere and resonance in a pseudo-steady electric scheme. The large range of measured magnetic fields in a gap uniquely guesses the need for realization of such meter of magnetic fields, in which the high measure of a linearity of frequency of an output signal is reached depending on tension of a measured magnetic field. According to idealized model it is reached provided that the concentration of an exciting magnetic field in bulk of sphere is great enough and is gentle changes in rearrangement, for what the sizes of closed loops of connection should be about radius of the sphere. The precise calculation of the relative sizes of closed loops and ferrite sphere implements at given electrodynamic parameters of a ferrite sphere, outgoing from the optimum coordination on an impedance of a source of oscillations and load. On this basis the designing was conducted, other characteristics - level of spurious resonances, an amplitude-frequency characteristic - are optimized at set-up, including by selection of optimal values of supply voltages on semiconductingstructure.

The designs of meters of magnetic fields of range 700-63000 oersted were designed, including design, in which one the hemispherical ferrite resonators are located in bulk of planar arsenide-gallic semiconductor devices (fig. 15, 16)

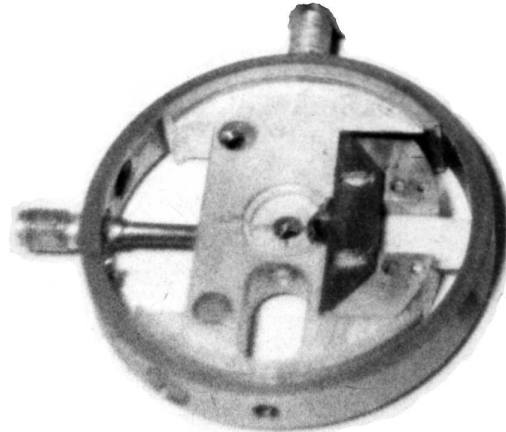


Fig. 15

intended for measurement of magnetic fields up to 13000 oersted with error, not of stimulus, superior 3 %, that satisfactorily for electrodynamic transportation facilities with a magnetic levitation [17].

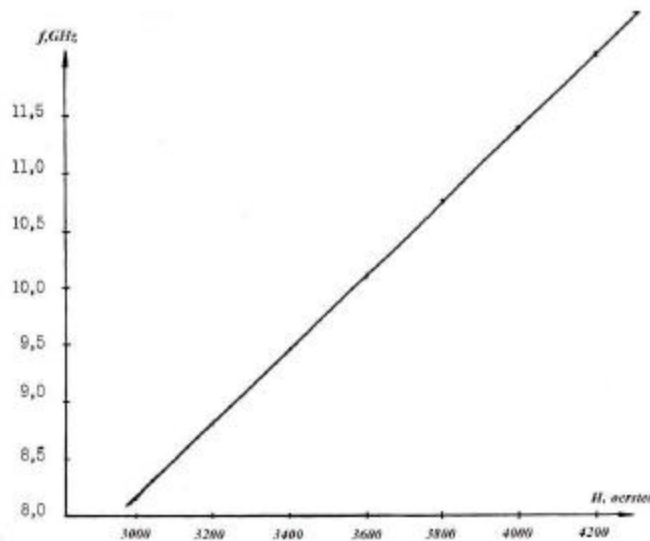


Fig.16

Phase compensators of electrical length

of sections of the marcer-connected waveguide.

In a developed radioinformation control system it is important to relevant the maintenance of a constance of electrical length of sections of the waveguide, physical length of which can change with temperature or owing to mechanical loadings. The indicated constance can be supplied at the usage of electrically controlled phase compensators (phaseshifters) which are engaged in a gap of regular segments of the marcer-connected waveguide. Naturally, that the indicated electrical devices should be energyî-strong and meet the requirements of electromagnetic compatibility.

In the largely measure to indicated requirements fit the phaseshifters, in which as an electrocontrolled reactivity the volumetric semiconducting structures on Gunn effect will be used, in which electrical activity (generation) is prevented at the expense of the localized contact development of negative differential conductivity [7] and at the expense of the conforming selection of microwave - load, so that semiconducting structure acts in a role of a high-Q solid-state controlled resonant circuit and plays a role of a phase member.

The designed phase compensator represents the modified wave-guide double T-bridge 1 (fig.17), for which the symmetrical unloosened shoulders are shifted and connected among themselves by an short-circuiting line 2 ("convolution").

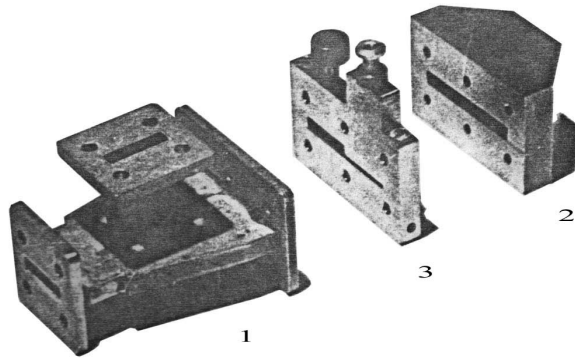


Fig. 17

The active semiconducting structure (its length of 30 microns, electron concentration $5 \cdot 10^{14} \text{ cm}^{-3}$) places in a twin flange 3, arranged between the bridge and short-circuiting line. The relation of a phase shift to a bias is adduced in a fig.18, thus the losses consist -2 dB (amplification) in a band not less than 5% from a center frequency of an input signal in an interval of intensities of a treated signal from 1 mcW up to 50 mcW.



Fig. 18

As it is visible, there is an extended enough linear segment of a phase characteristic, that allows to consider an introduced design of a phase compensator reasonable for the problem solving sounded in the given subsection.

Introducing a not full list of the items of information tangent the problems of elaboration of a radiowave informative system, it is possible to suppose, that the offered concept of a building of a control system can serve one of alternate in the solution of a problem of mission control of MLV with the electrodynamic suspension.

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