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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

THE USE OF THE KIRCHHOFF METHOD FOR ASYMPTOTIC SOLUTION OF A PROBLEM OF THE DIFFRACTION OF A PLANE WAVE ON DIELECTRIC BODIES OF REVOLUTION.

F. F. Izmaylov

Methods for computing a electromagnetic field vector after the passage of a plane wave through the dielectric walls of a surface of revolution are presented. An algorithm of geometric optics is given for a three-dimensional problem, and the diffraction field component which emerges due to the acute "nose" of the cone is taken into account by means of the Kirchhoff method. The calculation results are compared to experimental data.

INTRODUCTION

The problem of the diffraction of an electromagnetic wave on a dielectric cone is not being solved by strict methods at present. The passage of a plane wave through a surface of the conic type with radio-transparent single-layered or multi-layered walls is an even more complex electrodynamic problem. The available works on this problem [1, 2, 3, 4] use a plane model; i.e., the surface of revolution is replaced with a two-dimensional wedge with plane faces. The field inside the wedge is computed by means of coefficients of the passage of a plane wave through a plane parallel endless layer (geometric optics). Works [3, 4] have obtained the solution to a two-dimensional problem, which makes it possible to take into diffraction due to the edge of a wedge consisting of two half planes.

These results have not been extended to a three-dimensional case; at the same time, the solution of a three-dimensional problem is being stimulated by engineering needs, in addition to theoretical interest, since replacing a cone with a wedge is substantiated at present only by physical intuition and concepts of symmetry. In addition, calculation for a wedge is possible only in the main plane, and certain spatial effects theoretically cannot be obtained from a plane model.

This work has demonstrated that with the use of a stationary phase method for computing the vectorized Kirchhoff integral, one can take into account diffraction from the peak of the cone. An algorithm for computations according to geometric optics, which can be of independent interest for certain cases, is also presented.

The methods presented are oriented toward the use of ETsVM [digital computers], the need for which for obtaining sufficiently comprehensive quantitative results in such problems can raise no doubts.

GEOMETRIC INTERPRETATION OF THE POINTS OF A STATIONARY PHASE IN KIRCHHOFF'S FORMULA AND A METHOD OF GEOMETRIC OPTICS

The following problem is considered (Fig. 1): a plane electromagnetic wave falls from outside on a radio-transparent body formed by rotation of a layer with known characteristics around an axis x[1]:

[1]The time factor $e^{-i\omega t}$ is omitted throughout.

$$\bar{E} = \bar{e}\, e^{i\kappa \bar{a}\cdot\bar{R}},$$
$$\bar{H} = \frac{\kappa}{i\omega\mu}\left[\bar{a} \times \bar{E}\right].$$

The field at an observation point N situated in the inner region is to be found. With respect to the set of observation points, it will be assumed that they are situated on a plane y_1z_1 of a system of coordinates $o_1x_1y_1z_1$ *related to the main* system xyz by two angles α_1 and α_2 by means of the matrix M_1:

$$M_1 = \begin{vmatrix} \cos\alpha_1\cos\alpha_2 & -\sin\alpha_1\cos\alpha_2 & \sin\alpha_2 \\ \sin\alpha_1 & \cos\alpha_1 & 0 \\ -\cos\alpha_1\sin\alpha_2 & \sin\alpha_1\sin\alpha_2 & \cos\alpha_2 \end{vmatrix}.$$

Observation points sufficiently remote from the inner surface S for the condition $ik-1/r \sim ik$, where r is the distance from the observation point to an arbitrary point of the surface, and k is the wave number, to be fulfilled are considered.

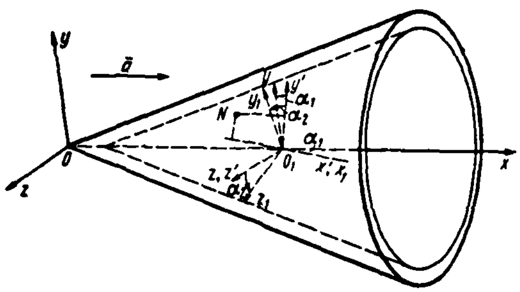

Fig. 1.

The incident field has an elliptical polarization, and in general, the matrix M_2 of the directing cosines of the propagation vector and the axes of polarization is defined by two angles θ_1 and θ_2 in relation to the system $o_1x_1y_1z_1$ and looks similar to matrix M_1. The geometric form of the generatrix $y=y(x)$ is assigned analytically or from a table, and the surface S is assumed to be closed on infinity.

COPHASED DIRECTED SURFACE WAVE SPLITTERS USING DIELECTRIC WAVE-GUIDES

D. I. Mirovitskiy, V. F. Dubrovin and V. V. Baskakov

The results of work on finding new methods for constructing functional units for UHF and integral optics equipment using single mode and dielectric wave-guides are presented. Four-armed and three-armed directed splitters constructed using rectangular polystyrene wave-guides according to symmetric and non-symmetric designs have been investigated.

INTRODUCTION

Interest in junctions on lines with surface waves has increased substantially [1]. This has been caused by the need for improving the characteristics of a number of devices in utilized ranges of centimeter and millimeter waves and advancing [2] into the region of shorter waves (submillimeter and infrared), which is not always possible with the use of components using metal waveguides and strip lines.

In an investigation of the propagation of slightly retarded electromagnetic waves in crossing dielectric waveguides and waveguides intersecting at an acute angle, a phenomenon uncharacteristic of devices constructed in a similar form using metal waveguides and coaxial lines was discovered. This phenomenon cannot be explained by the methods used in analyzing a distributed connection between waveguide and coaxial transmission lines and also valid for lines with surface waves with significant retardation [3]. The main features of the phenomenon detected were as follows:

- effective directed branching of energy from the main tract to a side tract throughout a broad frequency range (at least ±20%) at a limited (of the order of λ_0) length of the section of interaction between tracts;

- a cophased nature of the wave branched into the side tract with the wave propagated in the main tract.

Figure 1 presents experimental dependences of the level o the branched signal P_3 and its phase ϕ°_3 (in relation to the phase ϕ°_2 of the wave in the main tract) on the angle θ of intersection of the waveguides.

A monotonous increase in the signal P_3 passed into the side arm occurs on a section of angles from $\theta^{\circ} \simeq 90^{\circ}$ (the side tract intersects the main tract at a right angle) to $\theta^{\circ} \simeq 160^{\circ} \pm 3^{\circ}$. The curve $\Delta\varphi = f(0)$, which has an initial spread determined primarily by the error in measuring small phase shifts, attests to the inphase relationship of signals in the main and side tracts in this range of angles θ°. However, with an increase in the angle θ° above 160°, the picture changes sharply: the branched signal P_3 begins to decrease, and a significant shift appears in regard to the signal phase in relation to the signal in the main tract. This is conditioned by an increase in the section of interaction between the "wave tubes" of the two tracts at θ° angles exceeding 160°, which leads to the appearance of a normal distributed connection [3], characterized by counterphase signal separation. Adding a counterphase signal conditioned by the distributed connection to the inphase branched signal in the side tract leads to a decrease in the total signal P_3 on a section of angles $\theta^{\circ}=160-170^{\circ}$. With a further increase in the angle θ (above 170°), predominance of the counterphase signal in this total branched signal begins, leading to a subsequent increase in the signal P_3. The process described is the cause of the appearance of a minimum on the curve $P_3=f(\theta)$ in the region $\theta^{\circ}\simeq 170^{\circ}$.

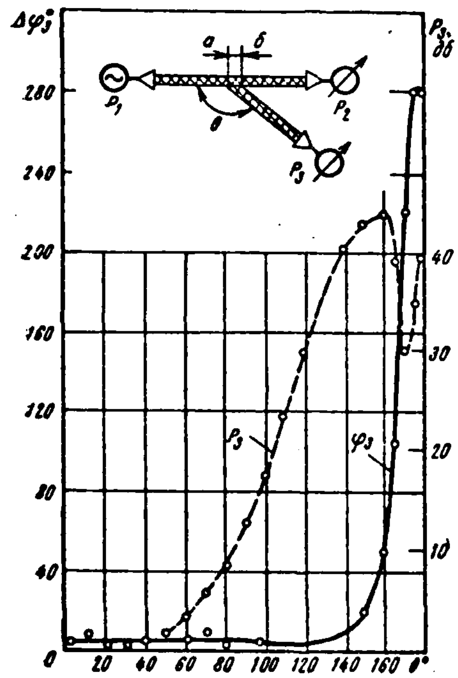

Fig. 1.

Thus, a local (on the λ_0 section) inphase connection is characteristic of the phenomenon of directed branching which has been observed. This has been verified directly by experiments with impermeable absorbing and metal screens introduced into the region of the intersection of the waveguides under investigation, i.e., screens covering closely placed sections, between which a distributed connection can exist. A change in the position of these screens does not substantially alter the amplitude and phase ratios of branched and main signals.

It should be noted that the phenomenon of inphase directed branching of electromagnetic energy in the lines under investigation is exhibited more sharply the lower the coefficient of reflection from the region of intersection of the lines. An explanation for this phenomenon has been found in an investigation of the amplitude-phase distribution of the electromagnetic field in the vicinity of a regular dielectric waveguide with slight retardation, on whose surface a discontinuity has been superimposed in the form of an insulator covering. It was demonstrated that radiation from the discontinuity has a directed character; its maximum is oriented in the direction of wave propagation in the waveguide (at an acute angle to the waveguide axis).

Amplitude-phase diagrams of the field characterizing the discontinuity radiation for three types (in the form of coverings of polystyrene) situated on a narrow wall of the waveguide are presented in Fig. 2. The breaking away of energy (radiation) occurs at an angle of $\sim 16^{\circ}$ in the case in Fig. 2a and at angles of $\sim 32^{\circ}$ and $\sim 80^{\circ}$, respectively, in Figs. 2b and 2c; this can be judged easily according to the form of equipotential curves (the solid lines) and the disposition of the phase fronts (dotted lines). The former were plotted every 10 db in relation to a signal transmitted along a main three-centimeter tract, while the latter were plotted every $\Delta\varphi^{\circ} \simeq 2\pi$, and recorded with a test probe connected to the side arm of a balanced phase measurement device. The investigations were conducted on a testing unit developed for this purpose [4].

An analysis of many diagrams obtained in this investigation led to the following qualitative explanation of the

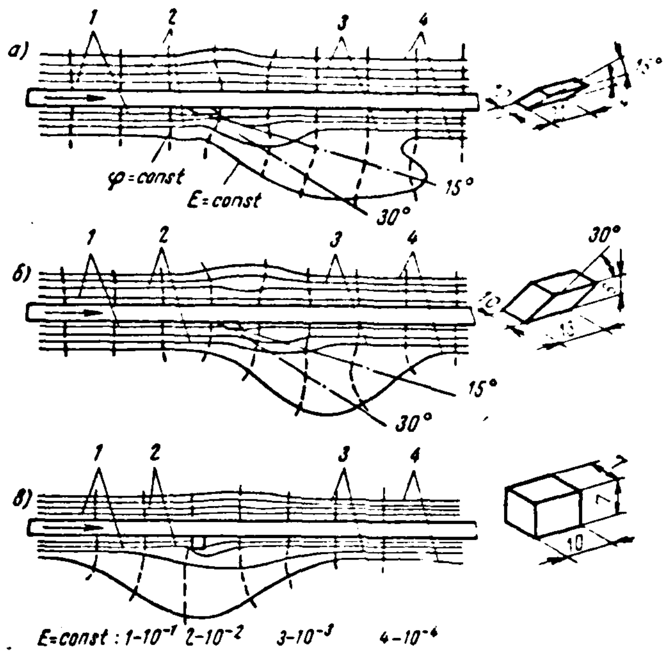

Fig. 2.

phenomenon: on the section of interaction (of two tracts) a-b (see Fig. 1), variation occurs in the directing properties of the main tract, and this disturbance causes directed radiation of energy, which is "captured" by the side tract. This has been confirmed by measuring the level of the signal (emitted by the discontinuity according to the scheme of Fig. 3) by means of a receiving dielectric rod antenna. Curves of the dependence of the signal P_3 at the antenna indicator on the angle θ (between the axes of the main tract and the antenna) for two discontinuities with different angles ψ of the cut-off of the faces attest to the fact that the change in the averaged signal in such a scheme coincides with the character of the change in the signal P_3 of the scheme of Fig. 1. The signal oscillation observed is explained by interference phenomena conditioned by the incidence of a signal of direct radiation from the exciting device of the main tract on the antenna.

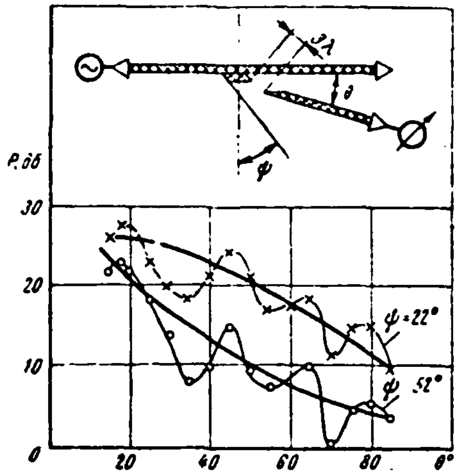

Fig. 3.

Thus, according to the results of experiments of Figs. 1 and 3, one can conclude that the drop in the signal P_3 on the curve of Fig. 1 at angles $\theta^{\circ} > 160^{\circ}$ is explained not only by the emergence of a distributed connection of the auxiliary tract with the main tract, leading to the appearance of a counterphase component in the latter. First this causes a drop in the signal P_3, and an increase in the distributed connection in a further increase in the angle θ° leads to almost spasmodic rotation of the phase of the signal P_3 (Fig. 1, solid curve) and a related increase at angles $\theta^{\circ} \geqslant 170^{\circ} (\pm 3^{\circ})$ of the signal P_3. In addition, the signal drop is explained, according to Fig. 3, partially by the "departure" of the side arm (the antenna) from the maximum of the discontinuity radiation pattern (Fig. 2).

It should be noted that the experimental data obtained are in good agreement with later theoretical research on smooth discontinuities in open waveguides [5].

A number of different devices, including spatially inphase and counterphase directed splitters and hybrid connections using dielectric waveguides [6, 7], have been created based on the effect discovered.

The results of investigations of various cophased directed splitters and couplers using dielectric waveguides, representing a continuation of works [8, 9], are presented below. Devices using rectangular waveguides with a cross section of 10x23 mm^2 of technical grade polystyrene $(\varepsilon \simeq 2{,}54,\ \mathrm{tg}\,\delta \simeq 4{,}3\ 10^{-4})$ were studied. Surface wave exciters differing from the normal devices in their use of semiconductor metal films [10] were used for transforming an H_{10} wave to TE_{01} in the transition from a metal waveguide to a dielectric waveguide. The overall appearance and a diagram of the connection of a symmetric four-armed splitter are presented in Fig. 4. In feeding of a signal into arm 1 (or 3), the signal

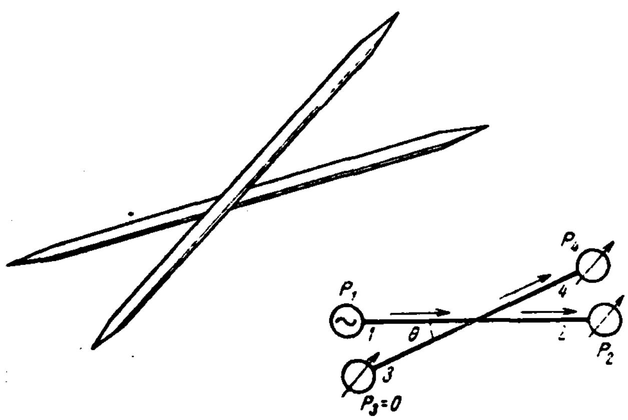

Fig. 4.

is divided between arms 2 and 4, with a division factor which depends on the angle of intersection of waveguides 1,2 and 3,4, the degree of coordination of the region of their intersection and the ratio of surface wave retardation factors in these intersecting waveguides. The latter are determined by the dimensions of the cross sections and by the parameters of the material. Since two identical waveguides were selected, a dependence of the division factor only on the angle θ° and the degree of coordination, which is partially determined by this angle, was observed. The signal P_1 fed into arm 1 from the generator almost does not pass into arm 3 (the signal P_3 is attenuated in relation to the signal P_1 by more than 40 db). The character of the change in signals in arms 2, 3 and 4 in a change in the angle θ° from 18 to 90° is shown graphically in Fig. 5. With an increase in the angle, the signal branched into side arm 4 decreases monotonously, while in a continuation of the main tract (arm 2), it increases. The isolation of the opposite arm 3 worsens beginning with an angle $\theta \simeq 40°$, which is conditioned [8] by an increase in the direct connection between the exciting devices of dielectric waveguides 1 and 3. The dependence of the ksvn [voltage standing wave ratio] at the input of the device on the angle θ° is represented by curve 1 in Fig. 6 and does not exceed 1.2. Signals in all the arms of this con-

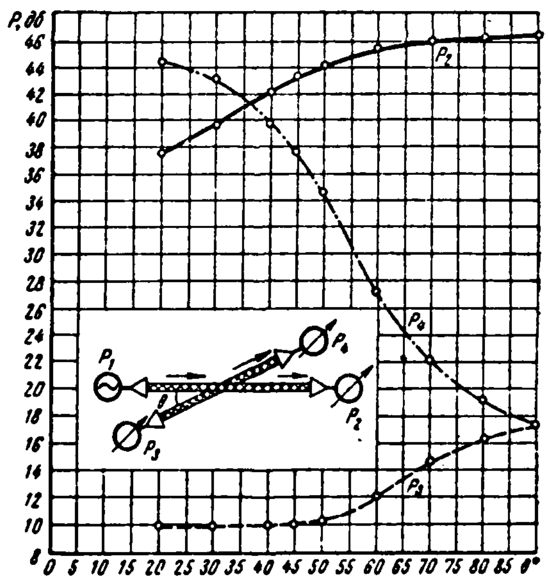

Fig. 5.

nection prove to be spatially cophased (in the range of angles θ° from 18±3° to 162±3°). It is noted that the patterns ob-

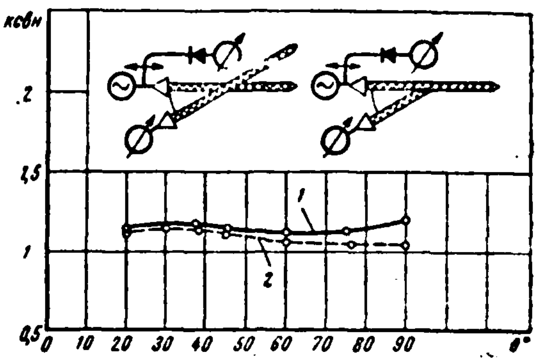

Fig. 6.

tained [11, 12] are preserved in a frequency band greater than ±20%. The overall appearance of a nonsymmetric four-armed splitter consisting of a main tract 1-2 and two side tracts 3 and 4 is shown is Fig. 7. This splitter performs the functions of a wide-band (Δf at least ±20%) directed coupler. The isolation of arms 3 and 1 at an angle $\theta \simeq 18° \pm 3°$ is at least 40 db, and the directivity is at least 31 db. The ksvn at the input is no worse than1.16, and the losses are no greater than 2.5 db. Improving the coordination of the waveguides in the region of their intersection made it possible to increase the splitter directivity to 40 db.

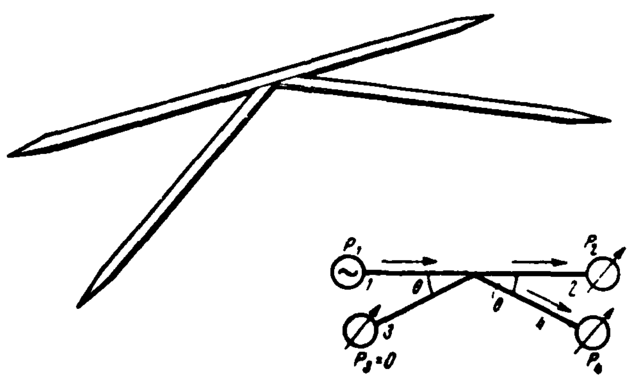

Fig. 7.

The overall appearance and a connection diagram of a three-

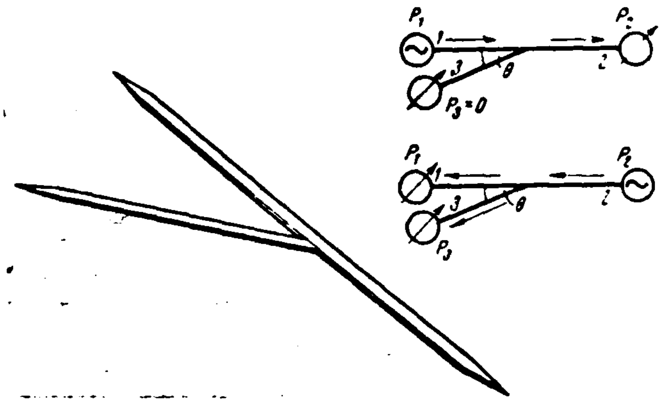

Fig. 8.

armed nonsymmetric splitter are presented in Fig. 8. The signal from arm 1 passes into arm 2, at an isolation of arm 3 of the order of 40 db. The signal fed into arm 2 is divided between arms 1 and 3 with a division factor depending on the same factors as in the four-armed splitter. The dependence of the factor of division of the signal between arms 1 and 3 on the angle θ^{o} is represented in Fig. 9. Losses in signal transmission from arm 1 to arm 2 amount to 5.6 db, with losses of about 2.6 db in transmission from arm 2 to arms 1 and 3. The difference of 3 db in the losses is explained, as research on the field distribution in the connection has demonstrated, by the presence of energy radiation in the direction of the continuation of arm 3, which forms a false arm 4. This is easily established in regard to the form of the equipotentials of Fig. 10 applied at levels 10^{-1} and 10^{-2} of the signal being transmitted, which "protrude" somewhat in the direction of the continuation of arm 3. The solid lines in the figure show a case in which the signal is fed from arm 1 to arms 2 and 3, and part of the signal reflected by the load in arm 3 is radiated in the direction of arrow A. The dotted lines conform to transmission of a signal from arm 2 to arm 1. The section of arm 3 adjacent to the main tract 2-1 which is excited in this case by a surface wave emits

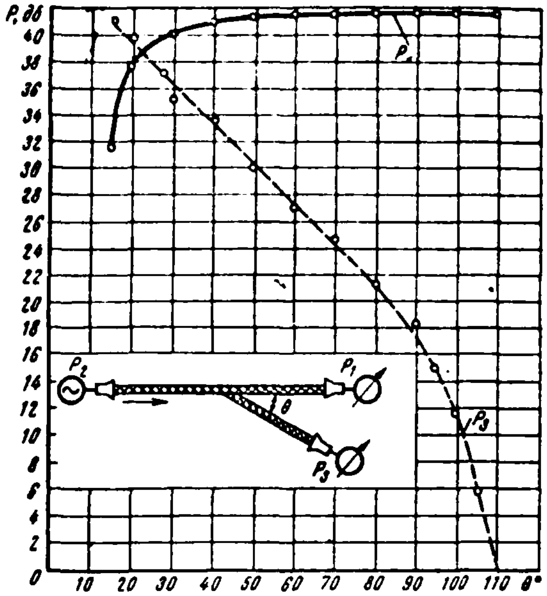

Fig. 9.

the energy again in the direction of arrow B. Thus, this three-armed splitter acts essentially as a four-armed connection (with one false arm) and has sharply pronounced directed properties.

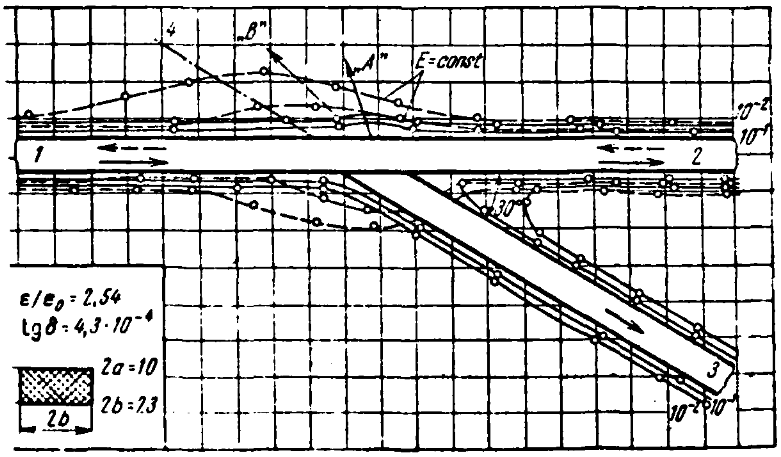

Fig. 10.

The dependence of the ksvn at the input of the device on the angle θ° is characterized by dotted curve 2 of Fig. 6.

An overall view of a three-armed by symmetric splitter with an angle θ° between the side arms 2 and 3 of the order of 18° and a connection diagram of the splitter are presented in Fig. 11. A signal fed into arm 1 is divided equally between arms 2 and 3 with a precision of less than ±2.5% at loss of the order of 2.5 db and a standing wave factor at the input not exceeding 1.16. Losses in signal transmission in reverse connection of the splitter, i.e., in feeding of the signal from arm 2 to arm 1, amount to 5.5 db, and the standing wave factor in arm 2 is preserved at a level of 1.16. The side arms 2 and 3 of the splitter are well insulated against each other (a connection of the order of -40 db); i.e., in feeding of a signal into one of the side arms, it almost does not branch off into the other. The field distribution in the splitter is shown in Fig. 12 with solid lines in feeding of a signal into arm 1 and dotted lines in feeding into arm 2. Losses in signal

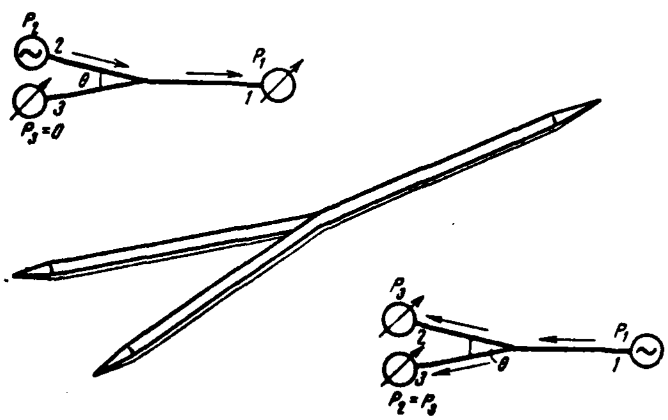

Fig. 11.

transmission from left to right exceed losses which occur in signal feeding from right to left (from arm 2 or 3 to arm 1) by 3 db, which, as before, is explained by the appearance of ra-

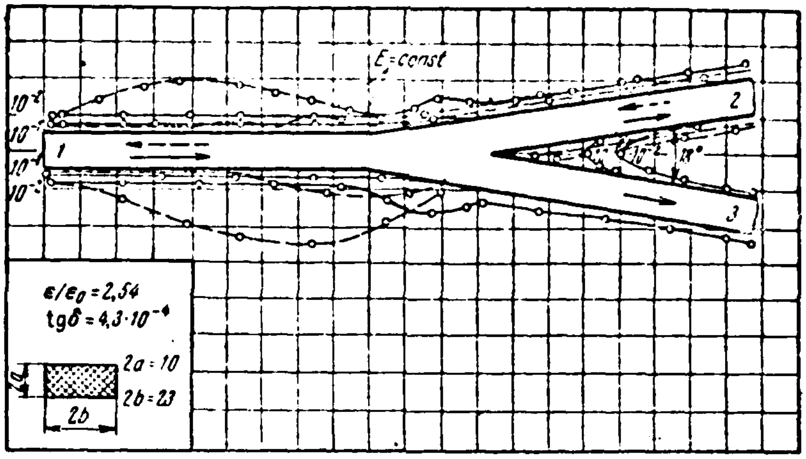

Fig. 12.

diation characterized by noticeable distortion of the equipotentials (dotted lines) in the region of intersection of the waveguides.

In the use of the splitter as a summer, i.e., in feeding of two signals at once into arms 2 and 3, their vector composition occurs in arm 1. The splitter is spatially cophased, which facilitates regulation of the phase difference of the signals being added by phase shifters situated in the waveguide tracts, connected to side arms 2 and 3. The field amplitude and phase distribution for this splitter is shown in Fig. 13 with solid lines in feeding of cophased signals to arms 2 and 3 and with dotted lines in feeding of counterphase signals. The character of the curves obtained attests to a strong effect of phase ratios of the signals being added on the intensity of radiation in the branching region. The radiation intensity actually increases substantially with an increase in the signal difference from 0 to π. In addition, the symmetric and weakly directed radiation at the point of branching of the waveguides takes on a directed character with the appearance of a phase shift in a case of cophasing of the signals being fed. Two

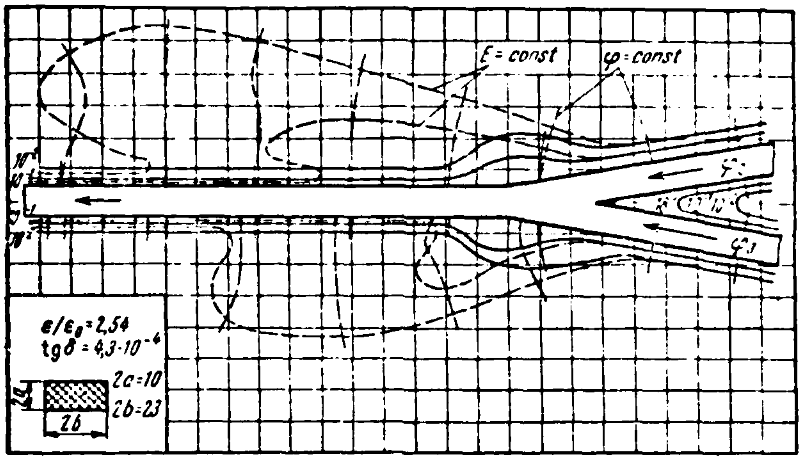

Fig. 13.

lobes of this radiation are oriented along the directions of continuation of side arms 2 and 3. It is significant that at a phase difference equal to π, the most intense radiation is observed in the direction of the arm with a signal which lags in regard to phase (i.e., in the direction of arm 2). The dielectric connection studied also preserves its characteristics in a frequency band of ±20%.

It should be noted in conclusion that all the data presented pertain to laboratory models of connections constructed from widely used insulation materials. The use of special high frequency plastics and ceramic materials with high dielectric permittivity levels (ε from 10 to 160) and lower losses ($tg\,\delta \simeq 10^{-4} \div 10^{-5}$) makes it possible, as research demonstrates, to improve significantly the operational characteristics of directed splitters (to reduce dielectric losses, reduce the dimensions, etc.).

Models of a number of measurement instruments and testing units have been developed based on the devices described [11, 12]. With appropriate design finishing, these devices will be promising for use in high-frequency sections of a number of different radio systems, such as in multicomponent antenna feeding devices.

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