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TELEVISION ANTENNAS FOR COMPLEX CONDITIONS OF RECEPTION,(U)
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TELEVISION ANTENNAS FOR COMPLEX CONDITIONS OF RECEPTION

By

V. Kuznetsov, V. Paramonov, A. Kukayev

FOREIGN TECHNOLOGY DIVISION

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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

TELEVISION ANTENNAS FOR COMPLEX CONDITIONS OF RECEPTION

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The reception of television frequently has to take place under conditions which are considerably different from normal. Such conditions (we will call them complex) take place on the boundary of the zone of direct visibility, outside of this zone, where the intensity of the field of the television signal is low, and also within the zone of direct visibility, where the absolute value of field intensity is sufficiently great, but the quality of reception is deteriorated by interferences or by reflected signals.

The basic requirement which is usually demanded of television antennas which are intended for reception under complex conditions is high efficiency. This is explained by the fact that highly effective antennas, in addition to their high gain factor, which is especially necessary for reception in areas with a low field intensity, possess still another advantage - a narrow directional pattern, making it possible to attenuate the reception of interfering signals which arrive from side directions.

At the present time the most widespread method for achievement of a high gain factor is the creation of complex antenna arrays, consisting of several sections of simpler antennas joined together in such a way that the signals from them are accumulated cophasally.

Antennas constructed on such a principle have been described more than once in the journal "Radio" (for example, in 1963, Nos 3, 8; in 1965, No 4, etc.). The main considerations which should be used as a guide in the construction of antenna arrays were also given in the journal (see "Radio" 1965, No 2).

However, cophased antenna arrays constructed on such a principle have a shortcoming which in many cases does not permit the achievement of satisfactory results when such antennas are used for reception under complex conditions. There is talk concerning the insufficiently high coefficient of protective action (KZD) of such antennas (by KZD is usually meant the ratio of the levels of signals received by the antenna from the direction of maximum reception and the direction opposite to it.). The fact is that with the grouping of the individual antennas - elements into a cophased array the KZD of the entire array is not improved, as this takes place with the gain factor, but is preserved approximately the same as that which the individual element (antenna) of the array had.

Elements, from which the antenna array is usually made up ("wave channel" and frame aerials and other antennas with resonance, tuned reflectors), either by virtue of their natural properties or because of the impossibility of achievement of fine tuning in practice, have an insufficiently high KZD. The use of elements with aperiodic, untuned reflectors (see "Radio," 1963, No 10) leads to excessive complication of the antenna array and an increase in its weight and cost.

The scientific-research institute of radio has developed antennas for the reception of television under complex conditions which are assembled from elements with tuned reflectors. These antennas are simple in design and devoid of the shortcoming indicated above, thanks to the method used in them for the construction and connecting of the antenna array.

For an explanation of this method we will consider two identical antennas, oriented on the direction of maximum reception to one side (direction A in Figure 1), but shifted in this direction in respect to each other by a distance, equal to one fourth of the operating length of the wave.

For the sake of simplicity of discussion we will consider that both antennas operate on transmit (by virtue of the known principle of mutuality the directional properties of the antenna do not depend on whether it operates on reception or on transmission) and we will assume that the phase of the voltage which is powering antenna 2 lags behind by 90° from the phase of the voltage which is powering antenna 1. Under such conditions in the far zone the field intensities of the waves emitted by each of the two antennas in direction A will have the same phase and, consequently, be accumulated, and the waves emitted in direction B - opposite phases and mutually deducted.

Actually, if it is considered that in the point of observation, taken in the far zone in direction A, the field intensity of the wave emitted by antenna 1 has a phase, accepted conditionally as zero, then in respect to it in this same point the field intensity of the wave emitted by antenna 2 will, on the one hand, have a lead in phase by 90° due to the spatial shifting of antenna 2 in this direction forward by one fourth of a wave, and on the other - will delay by 90° due to the lag in phase of the powering voltage. The resulting shift is equal to zero and, consequently, the field intensities of the waves emitted in this direction by both antennas are cophased and added up. At the same time in a point of observation taken in the far zone in direction B, if again the phase of the field intensity of the wave emitted by antenna 1 is accepted as zero, the field intensity of the wave emitted by antenna 2 will experience a twofold lag in phase by 90°: one time due to the fact that in the direction of this point of observation antenna 2 is located further than antenna 1 by a fourth of a wave (spatial lag), and a second time due to the lag in phase of the power voltage. The resulting shift will be equal to 180° and, consequently, the field intensities of the waves emitted by antennas 1 and 2 in direction B will be mutually subtracted. Under the condition of identity of antennas theoretically it is possible to exclude back radiation completely, i.e., to obtain an infinitely high KZD. Under real conditions

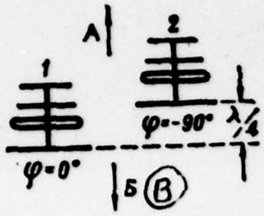

Figure 1.

naturally this does not take place, but a sharp attenuation of back radiation (reception) actually takes place. The described method for achievement of a high degree of suppression of the minor lobe of the directivity pattern can be repeated several times in the antenna array, including in pairs the individual elements, pairs of elements, whole sections or tiers, and, finally, half of the entire array.

As it follows from the description of the method given above, it is expedient to conduct the connecting of elements or parts of the array by pairs with the help of a device which ensures the addition of the power of two signals which are the same in level and shifted in phase by 90° (in the transmitting variant the division of power into two equal parts, differing in phase by 90°). Such properties are possessed by the so-called three-decibel directional coupler, representing a segment of two connected electromagnetic lines with geometric dimensions which ensure the obtaining of the required characteristics: electrical length, equal to one fourth of the operating length of the wave, a coefficient of power division equal to two, and input resistances which correspond to the wave resistances of the connecting lines.

A conditional representation and connection circuit of a directional coupler in the transmitting variant is shown in Figure 2, where the following designations are accepted: P - total power, arriving on its input, φ - angle, characterizing the phase of the voltage in a given point, R - ballast resistor, equal in magnitude

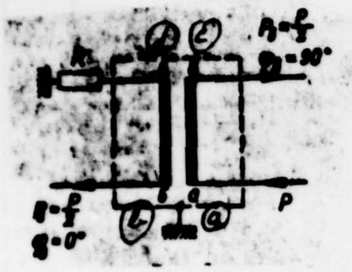

Figure 2.

to the wave resistance of the connecting lines leading up to the coupler. In a correctly made coupler, loaded for balanced loads, all the power supplied to the lead a is divided between leads b and c, and is not absorbed in resistor R. If the loads connected up to leads b and c are not matched completely, then the reflected waves do not pass from one outlet to another, but are absorbed in the ballast resistor. Under the condition of identity of loads all the power of the reflected waves is absorbed in resistor R and does not enter the transmitter. Thus a directional coupler, in addition to the division of power and the obtaining of the required phase relationships, ensures the satisfactory matching of the antenna system with the transmitter (receiver) and bypassing between the individual elements of the system. The latter means a high degree of reliability in operation, since in the event an array of any element or a sector of the system for powering of the antenna array goes out of order (break, shorting, etc.) the antenna system will operate (with a lowered gain factor). For a comparison it can be noted that in an ordinary cophased antenna array such damage can put the entire system out of order completely due to resonance phenomena in the broken or shorted segment of the line.

In accordance with the principle of operation the greatest effect of suppression of the minor lobe of the pattern can be obtained in a limited range of frequencies, the middle frequency of which corresponds to the operating wavelength. In practice, however, even on the lowest frequencies of the television band within one channel (48.5-56.5 MHz) it is possible to obtain considerable (up to 30 dB and more) suppression of the minor lobe of the pattern. With an increase of frequency the absolute width of the band of frequencies, within which a significant effect of suppression of the minor lobe takes place, increases, and correspondingly there is an increase in the number of television channels which the antenna can receive with a high KZD.

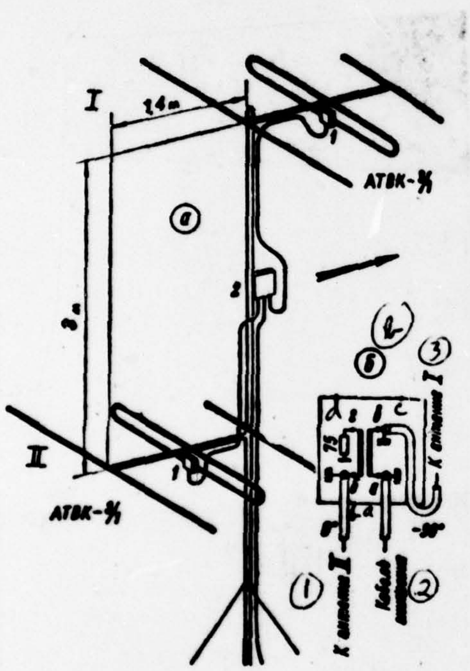

Figure 3.
Key: (1) To antenna II; (2) Downlead cable; (3) To antenna I.

In Figures 3, 4 and 5 general views are given for three antennas which are constructed using the method described. The arrangements for connecting up the elements are also explained by these drawings. Antenna 1 (Figure 3, a) is calculated for operation in the range of frequencies of the first television channel (48.5-56.5 MHz). It consists of two antenna arrays of the ATVK 3/1 [ATBH] type, located on one mast with a mutual shifting of 1.4 m on the direction to the

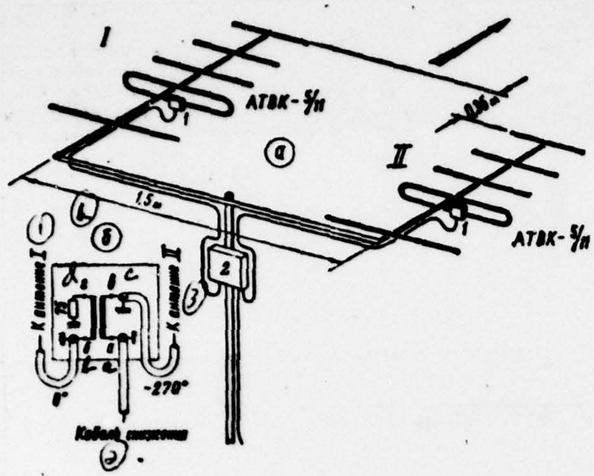

Figure 4.
Key: (1) To antenna I; (2) Downlead cable; (3) To antenna II.

television broadcast station. The vertical spacing between arrays from considerations of design convenience is take equal to 3 meters, i.e., less than the wavelength - a distance which is optimal from the point of view of obtaining the maximum gain of the antenna array. The arrays are connected together by a downlead cable with the help of a three-decibel directional coupler 2 (Figure 3,b). The connecting cables are 75-ohm coaxial, of the same length. Hooking up of the cables with the loop vibrator can be done with the help of any of the devices for matching and balancing, described also, just as the ATVK-3/1 antenna, in the article "Collective television antennas" ("Radio," 1969, No 3, p 26).

The design of the directional coupler and the method of connecting it with the cables are explained by the drawing 6, where a general view of the coupler with the cover removed, the housing for its lines with the winding and the core are depicted. As is evident from this drawing, the coupler consists of two electromagnetically connected nonsymmetric lines, twisted into spirals. For obtaining the required wave resistances and coefficient of division each of the lines is made out of two wires, the ends of which are connected in

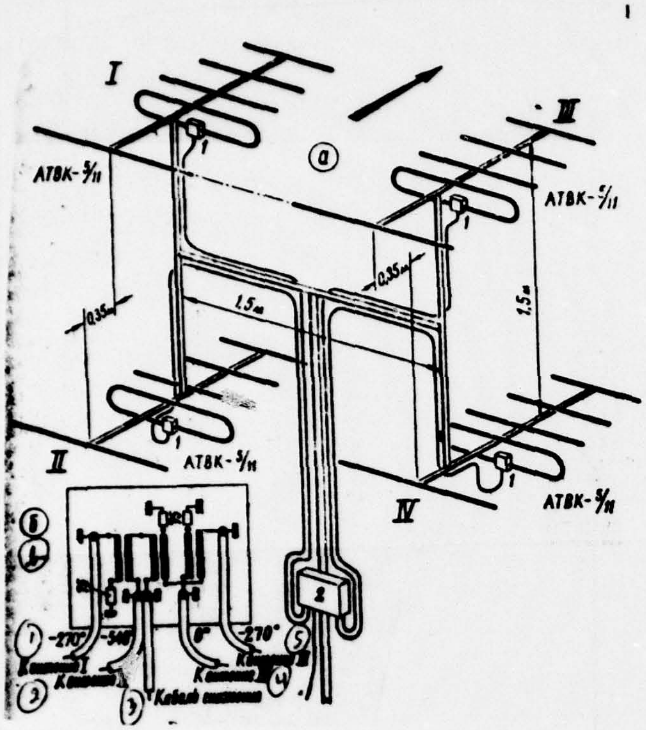

Figure 5.
Key: (1) To antenna I; (2) To antenna II; (3) Downlead cable; (4). To antenna IV; (5) To antenna III.

parallel. These wires are stored in the grooves of a four-thread [screw], as this is shown in Figure 6, b.

The housing, 9 mm in diameter, is made out of organic glass. On its outer surface there is a four-thread [screw] SpM9x(4x0.625). The winding is made with wire PEV-1 or PEL 0.27 mm. The number of turns in each pass of the thread is 24. Inserted tightly inside the housing is a rod made out of copper or brass tubing with an outer diameter of 7 mm and wall thickness of 0.5-1 mm. On the ends of the tubing from one side slots 1.5 mm in width and 18 mm in length are made (Figure 6, c). Between leads a and b, and also c and d, capacitors with a capacitance of 2-5 pF are hooked up for compensation of the end effects.

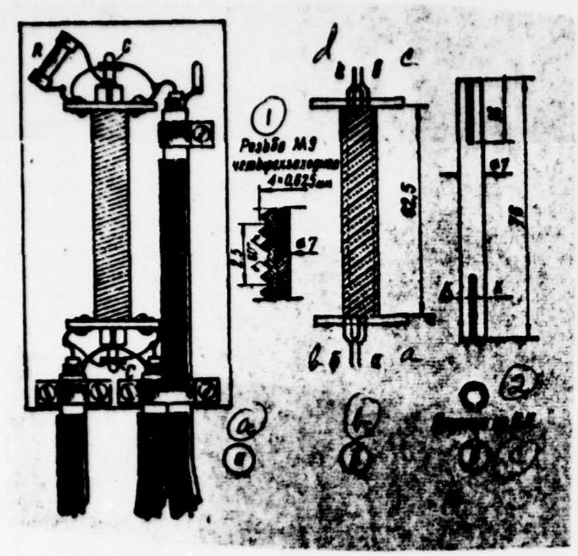

Figure 6.
Key: (1) M9 screw thread, four-thread 4x0.625 mm; (2) Section through KK.

A coupler produced in this manner in the range of the first five television channels (48.5-100 MHz) has a transmission factor into the leads b and c of an order of 3.7 dB with an irregularity of around $\pm$0.5 dB. Losses in it comprise around 0.7 dB.

Antenna 2 (Figure 4,a) is calculated for operation in the frequency band of 11 channels (214-222 MHz). In it they use ATVK-5/11 antenna arrays, which in contrast to antenna 1 are dispersed not along the vertical, but along the horizontal. The extent of dispersion is 1.5 m, and the shift in the direction of the television broadcast station is 0.35 m. The directional coupler 2 in antenna 2 is used the same as in antenna 1 (Figure 4,b). The transmission factor of the coupler, its irregularity and extent of internal losses in the frequency range of 174-230 MHz are somewhat greater than in the range of 48.5-100 MHz. The shift of the lattice arrays and their hook-up to the coupler should be done in the same manner as is shown in Figure 4.

Antenna 3 (Figure 5,a) is also calculated for operation in the frequency band of 11 channels and is formed out of four arrays of

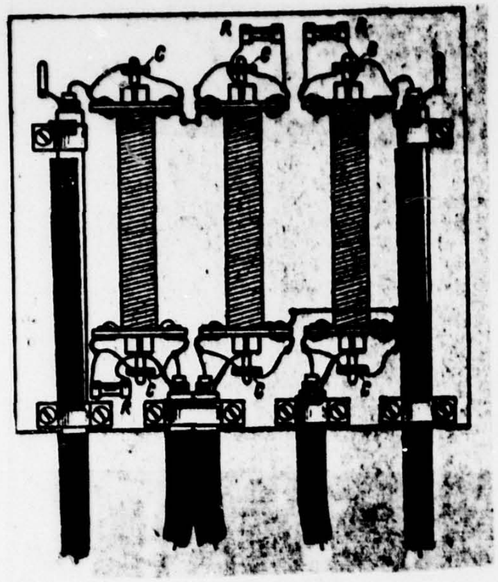

Figure 7.

the ATVK-5/11 type, spread out along the vertical and the horizontal by 1.5 m. In this antenna a twofold suppression of the minor lobe of the radiation pattern is realized: one time between the individual arrays, and a second time between the pairs of arrays. In antenna 3 a block of directional couplers is used which consists of three similar couplers of the type described above (Figure 5,b). The arrangement of their hook-up is also shown in Figure 5,b. A general view of the block is shown in Figure 7.

Shifting on the direction to the television broadcast station, equal to 0.35 m, can be done either as is shown in Figure 5,a, i.e., arrays 1 and 3 are positioned without a mutual shift, array 2 is shifted back, and array 4 forward in respect to arrays 1 and 3, or, which is convenient from a design point of view, the same as this was done above, but with a shift of array 2 not to the rear, but forward (or array 4 not forward, but back) in respect to arrays 1 and 3 with the simultaneous rephasing of the corresponding arrays (2 or 4) by 180°. Such a rephasing can be realized readily by means of alteration of the positions of the ends of the balancing-matching devices 1 from the balanced side on these arrays.

The brief descriptions of the three antennas given above are only examples. Using this principle and with the help of the directional couplers described it is possible to make up an antenna which is calculated for operation in any channel and consists of any even number of arrays. IN this case it should be noted that an antenna, calculated for operation in any one specific channel, has an increased KZD also in the frequency band of the neighboring channels; with other conditions equal, dispersion on the horizontal is more suitable than dispersion on the vertical, since in this case the antenna radiation pattern of the lattice is narrowed in the horizontal plane, which is important in the sense of reducing the possibility of reception of interfering signals.

Let us consider the question of selection of an antenna for reception in complex conditions. It has been established that in view of the modern tubes which are used in the input stages of television sets and antenna amplifiers, for the obtaining of an excellent or good quality of image it is necessary to supply to the input of the television set a signal with a level of 400-600 μV. In individual cases it is possible to permit a lowering of signal level to 200 μV, which corresponds to a still sufficiently satisfactory quality of image. A further lowering of input voltage can lead to an inadmissible deterioration of the quality of the image, the same as an increase in the influence of external noises in the case of an unchanged or even a higher level of voltage.

In order to avoid misunderstanding it is necessary to note that the sensitivity which usually appears in the technical data for any television set, very frequently having an order of 50-100 μV, characterizes only the amplification capacity of the set (it is numerically equal to the voltage which must be supplied to the input of the set in order that, with contrast adjustment set on the maximum, a nominal voltage is obtained on the output of the set, i.e., normal contrast). In this case the quality of the image can be very low.

Thus if the field intensity of the television signal at the point of reception is known (and it can be determined quite simply with the help of a measuring receiver or a comparator), it is possible, having assigned a voltage necessary for ensuring the desired quality of image, based on known formulas to determine the required magnitude of the antenna gain factor. Based on the magnitude of the gain factor and taking into account local peculiarities (the presence and direction of arrival of interferences and reflected signals) it is possible to determine the degree of complexity and the structural layout of the antenna which should be used under the particular conditions.

In conclusion the following has to be noted. The most characteristic case of reception of television under complex conditions is the so-called long-distance reception of television, i.e., the reception of television stations which are located far (up to several hundred or even thousand km) beyond the limits of the zone of direct visibility.

It is known that the waves of the uhf range undergo scattering on the discontinuities of the layers of the atmosphere (troposphere and ionosphere). The number and degree of discontinuities , and consequently the possibility of further dispersion, depend on many factors: relief of the terrain, state of the atmosphere, solar activity, time of day and year, number and intensity of meteors, etc. On the average the level of the scattered field at the point of reception, located far (up to several hundred km) beyond the limits of the zone of direct visibility, is severl tens of dB lower than the level, which would take place in the case of dissemination for the same distance in free space. This level is not sufficient for reception of television even on the most complex antennas. In the case of a sharp increase in the heterogeniety of the atmosphere due to the influence of some factor or in the case of a favorable combination of a number of factors the conditions for dissemination can be improved considerably. The level of the field in the far zone in such cases can increase sharply (by several tens of db) and the reception of long-distance television stations become possible even on ordinary individual antennas.

It is natural that under such conditions the long-distance reception of television bears an irregular, random naturem. Furthermore, numerous sources of interference, located on a lengthy path of dissemination of a television signal, frequently lower the signal/noise ratio so much that the quality of the image turns out to be very poor. It is clear that in this case the application of even the most complex antennas and the most modern antenna amplifiers cannot save the situation. To the point relative to antenna amplifiers it is necessary to note that their application is justified actually in rare cases: for example, for compensation of signal attenuation in a long cable, connecting the antenna with the television set (in this case the amplifier should be located at the antenna), or in the case of division of the signal for several users. In other cases, when the signal/noise ratio is not sufficiently great, the use of an antenna amplifier does not yield an effect, since its noise is of the same order as that of the television itself.

It would be desired that all those who show an interest in long-distance reception of television would represent clearly all the possibilities of this type of television reception. Unfortunately, there are still very frequent cases when people, having heard or read something about long-distance reception of television, arrive at the mistaken conclusion that it is sufficient to make the antenna more complex, to raise it higher and to hook up an antenna amplifier in order to regularly and with a high quality pick up television broadcast stations which are located far beyond the limits of the zone of direct visibility. As a result there is dissatisfaction, caused by the nonconformity between the expenses being borne and the results obtained, and also, and perplexed letters to the editors of the journal "Radio."

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