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(FOUO 2/79)

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ADB TELECOMMUNICATIONS LOAN--Two loans amounting to 10 million units of account, or approximately 2,857 million francs CFA have been granted by the Arabl Development Bank (BAD) to Gabon following an agreement signed on 5 December in Abidjan at this institution's headquarters. These loans will be used by the Gabon Office of Post and Telecommunications to finance a telecommunications development project in Port-Gentil, Franceville, Moanda, Ndjole, Lambarene, Oyem, Bitam, Mouila and Koula-Moutou, as well as to remodel and increase the Libreville telephone network. These loans, which are guaranteed by the Gabonese government, are fifth in a series of ADB grants to Gabon, now totaling more than 23 million units of account. [Text] [Paris MARCHES TROPICAUX ET MEDITERRANEENS in French 22 Dec 78 p 3510]

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EVALUATION OF ELECTROMAGNETIC COMPATIBILITY CONDITIONS IN THE OPTIMIZATION OF RADIO RELAY LINE CONSTRUCTION

Moscow ELEKTROSVYAZ' in Russian No 9, Sep 78 pp 1-7

[Article by A. I. Kalinin and V. A. Shamshin, submitted 6 June 1978]

[Text] The article published below deals with the proplems of technical and economic optimization of the construction of radio relay lines whose discussion was started in [1], particularly the possibility of improving the conditions of electromagnetic compatibility (EMS) when the energy parameters of the radio relay equipment are lowered to values which would allow to maintain the required quality indexes of the radio relay line channels.

Introduction. The advisability of the technical and economic optimization of the construction of RRL [radio relay lines] is determined by the fact that new generations of radio relay equipment will be created exclusively on the basis of semiconductor devices and integrated circuits [1]. One of the most important aspects of optimization is the reduction of the levels of signals from radio relay equipment interfering with other communication systems working within the same frequency range.

The following kinds of interference are possible in shared frequency bands allocated for systems of fixed ground communication and communication systems with the use of artificial earth satellites (ISZ) [2]: between geostationary communication or broadcasting ISZ and radio relay stations (RRS); between RRS and ground stations (ZS) of communication or broadcasting systems with the use of ISZ; between RRS of territorially separated RRL and between RRS of the same RRL.

When ISZ with highly elliptic orbits are used, the interference is insignificant because of the small probability of the effect of interference caused by the narrowness of the radiation pattern of the RRS antennas and the high rate of the ISZ movement with small angular altitude.

Interference Between Geostationary ISZ and RRS. The Radio Communication Regulations [2] established the maximum permissible effective radiated power from RRS in the direction of a geostationary orbit as 47 dBW within the frequency range of 1-10 GHz and 45 dBW within the range of 10-15 GHz. At the same time, the maximum effective radiated power of an RRS must not be more than 55 dBW.

Consequently, if in the process of the optimization of the construction of an RRL, it will prove to be practical to reduce the radiation power even by 8-10 dB, then the airborne receivers of ISZ will be almost completely protected against interference from RRS. This will remove limitations imposed on the configuration of the RRL construction and in many instances may lead to a noticeable reduction in the construction and operation costs of RRS.

Let us determine the relation of the noise power to the power of the useful signal at the output of the receiving antenna of an RRS under the effect of the radiation of an airborne ISZ transmitter with power flux density Π for an extreme case when the maximum of the directional pattern (DN) of the RRS receiving antenna is oriented toward the ISZ.

The propagation of the interfering signal takes place in the conditions which are close to the free space conditions, therefore, the power of the interfering signal at the output of the RRS receiving antenna

$$P_{2\text{м}} = \Pi \frac{\overset{(1)}{\lambda^2_{\text{ИСЗ}}}}{4\pi} G_{2\,\text{РРС}}^{(2)}, \qquad (1)$$

Key: 1. ISZ
2. RRS

where λ_{ISZ} is the length of the wave radiated by the airborne transmitter of the ISZ; G_{2RRS} is the gain of the receiving antenna of the RRS. The power of the useful signal at the output of the receiving antenna of the RRS not exceeded in the course of T percent of time of the worst month is

$$P_2(T) = \frac{P_1 G_{1\,\text{РРС}} G_{2\,\text{РРС}} \lambda^2_{\text{РРС}}}{16\pi^2 R^2} V^2(T), \qquad (2)$$

where P_1 is the power delivered to the RRS transmitting antenna with gain $G_{1\ RRS}$; V(T) is the value of the attenuation factor of the free space field for the useful signal not exceeded in the course of T percent of time; R is the length of the RRL interval.

Assuming that $\lambda_{ISZ} = \lambda_{RRS}$, on the basis of formulas (1) and (2), we shall find

$$\frac{P_{2\text{м}}}{P_2(T)} = \frac{4\pi \Pi R^2}{P_1 G_{1\,\text{РРС}} V^2(T)}. \qquad (3)$$

According to [2], in the frequency bands 1.7-2.535; 3-8; 8-11.7; 12.5-15.4 GHz allocated for joint use by ground communication systems and communication systems via ISZ, the maximum permissible power flux density in the frequency band of 4 kHz, when the angles of arrival of radiation over the horizontal plane are less than 5°, $\Pi_1 = -(154\text{-}148)$ dBW/m^2. Considering that the pass band of receivers in modern radio relay systems and communication systems using ISZ is approximately equal to 40 MHz and assuming that $\Pi_1 = -150$ dBW/m^2, we find from (3) the maximum permissible value of $\Pi = 10^{-11}$ W/m^2.

Since the value of $P_{2M}/P_2(T)$ changes at random in time, the power of noise in the channels of the line caused by interference is also a random function of time. In accordance with the MKKR [International Radio Consultative Committee] Recommendations[3], the norm for a permissible increase of the average power of noise per minute in the channels of a hypothetical standard line due to the influence of all sources of interference is 1000 pW in no more than 20% of time and 50,000 pW in no more than 0.01% of time of any month.

For modern RRL, $R \approx 50$ km and according to averaged curves of statistical distribution of V(T) for the frequency of 4 GHz [4] we have V(20%) = 0.63 (-4 dB), V(0.01%) = 4.47×10^{-2}(-27 dB). Consequently, in the case of the usual parameters of radio relay equipment $P_1 = 10$ W, $G_{1\,RRS} = 10^4$ and $\Pi = 10^{-11}$ W/m^2, from (3) we have $P_{2M}/P_2(20\%) = 7.8 \cdot 10^{-6}$(-51 dB), and $P_{2M}/P_2(0.01\%) = 1.58 \cdot 10^{-3}$(-28 dB). Let us consider that the frequencies of the useful and the interfering signals coincide and their spectral characteristics are approximately identical. On the basis of [5,6] it is easy to find that, in transmitting multichannel telephony, the noise power in radio relay systems with a capacity of 600-2000 channels caused by interference from ISZ will exceed 200 pW in the course of 20% of time and 38,000 pW in the course of 0.01% of time.

Let us assume that in the process of the optimization of RRL construction it was found practical to reduce R to the limit values given in [1] and to lower the energy parameters of the equipment by approximately 20 dB. The limit value of R for the frequency range of 4-6 GHz is approximately 15 km, while V(20%) $\approx$ 1, V(0.01%) = 0.143 (-14 dB) [1]. On the basis of formula (3) and works [5,6], we find that the power of the noise in the RRL channels caused by interference from the ISZ will exceed 750 pW in the course of 20% of time and 19,000 pW in the course of 0.01% of time.

The obtained figures indicate that the conditions of the fulfillment of the MKKR Recommendations [3] for the noise level in RRL channels under the effect of radiation from ISZ in cases of shortened intervals and average levels of signals lowered by 20 dB turn out to be approximately the same as for the intervals of the ordinary length and the existing parameters of radio relay equipment. The only difference is that, in the case of intervals of the usual length, due to great time-dependent changes in the level of the useful signal, the determining norm is the norm for the level of noise exceeded in the course of 0.01% of time, and in the case of shortened intervals and lowered energy parameters of the equipment -- the norm for a level of noise exceeded in the course of 20 % of time.

Interference Between RRS and Ground Stations of Communication Systems Using ISZ. The power of the interfering signal $P_{2M\ ZS}(T)$ at the output of the receiving antenna of the ZS from RRS exceeded in the course of T percent of time can be expressed in the general case as follows:

$$P_{2\text{м}\,\text{ЗС}}(T)=\frac{P_1 G_{1\,\text{РРС}}\,G_{2\,\text{ЗС}}\,\lambda^2_{\text{РРС}}}{16\pi^2 R^2_{\text{м}}}\times$$
$$\times F^2_{\text{РРС}}(\varphi)\,F^2_{\text{ЗС}}(\varphi_{\text{ЗС}},\Delta_{\text{ЗС}})\,V^2_{\text{м}\,\text{РРС}}(T), \qquad (4)$$

where R_M is the distance between the RRS and the ZS; $G_{2\ ZS}$ is the gain of the receiving antenna of the ZS; $F^2_{RRS}(\varphi)$ is the attenuation due to the DN of the transmitting antenna of the RRS at a given value of the azimuthal angle φ at the RRS; $F^2_{ZS}(\varphi_{ZS}, \Delta_{ZS})$ is the attenuation due to the DN of the receiving antenna of the ZS at the given values of the azimuthal angle φ_{ZS} and the angular altitude Δ_{ZS} at the ZS; $V_{M\ RRS}(T)$ is the value of the attenuation factor for the interfering signal exceeded in the course of T percent of time and dependent on R_M, λ_{RRS}, geographic and climatic conditions along the route between the RRS and ZS.

Let us consider that the conditions of the radio wave propagation along the ISZ-ZS route are close to the free space conditions. Then the power of the useful signal at the output of the receiving antenna of the ZS will be:

$$P_{2\,\text{ЗС}}=\frac{P_{1\,\text{ИСЗ}}\,G_{1\,\text{ИСЗ}}\,G_{2\,\text{ЗС}}\,\lambda^2_{\text{ИСЗ}}}{16\pi^2 R^2_{\text{ИСЗ}}}, \qquad (5)$$

where $P_{1\ ISZ}$ is the power of the airborne transmitter on the ISZ; $G_{1\ ISZ}$ is the gain of the transmitting airborne antenna; R_{ISZ} is the length of the ISZ-ZS route. Consequently, at $\lambda_{RRS} = \lambda_{ISZ}$

$$\frac{P_{2\text{м}\,\text{ЗС}}(T)}{P_{2\,\text{ЗС}}}=\frac{P_1\,G_{1\,\text{РРС}}\,R^2_{\text{ИСЗ}}}{P_{1\,\text{ИСЗ}}\,G_{1\,\text{ИСЗ}}\,R^2_{\text{м}}}\times$$
$$\times F^2_{\text{РРС}}(\varphi)\,F^2_{\text{ЗС}}(\varphi_{\text{ЗС}},\Delta_{\text{ЗС}})\,V^2_{\text{м}\,\text{РРС}}(T). \qquad (6)$$

The ratio of the power of the interfering signal from the ZS $P_{2M}(T)$ exceeded in the course of T percent of time at the output of the receiving antenna of the RRS to the power of the useful signal $P_2(T)$ not exceeded in the course of T percent of time

$$\frac{P_{2\text{м}}(T)}{P_2(T)}=\frac{P_{1\,\text{ЗС}}\,G_{1\,\text{ЗС}}\,R^2}{P_1 G_{1\,\text{РРС}}\,R^2_{\text{м}}}\,F^2_{\text{РРС}}(\varphi)\times$$
$$\times F^2_{\text{ЗС}}(\varphi_{\text{ЗС}},\Delta_{\text{ЗС}})\,\frac{V^2_{\text{м}\,\text{ЗС}}(T)}{V^2(T)}, \qquad (7)$$

where $P_{1\ ZS}$ is the power of the ZS transmitter; $G_{1\ ZS}$ is the gain of the transmitting antenna of the ZS; $V_{M\ ZS}(T)$ is the value of the attenuation factor for the interfering signal from the ZS exceeded in the course of T percent of time, and $F^2_{RRS}(\varphi)$ and $F^2_{ZS}(\varphi_{ZS}, \Delta_{ZS})$ denote now the attenuation due to the DN of the receiving antenna of the RRS and transmitting antenna of the ZS.

Let us evaluate the values of (6) and (7) by examining two extreme cases.

1. The attenuation of the level of noise due to the DN of the antennas is small. Moreover, the mutual interference of the RRS and ZS shows itself at large R_M, when the variance of the time-dependent changes in the level of the interfering signal is considerably greater than the variance of the changes in the useful signal even at the ordinary lengths of the RRL intervals. Consequently, as a first approximation, it is possible to disregard the time-dependent changes in the useful signal at the output of the receiving antenna of the RRS, assuming in (7) that V(T) = 1. In this case, for identical attenuation of the levels of the interfering signals due to the DN of the antennas under the effect of interference from RRS to ZS and from ZS to RRS, we shall find the relation of (6) and (7)

$$X_1 = \frac{P_1^2 G^2_{1\ \text{РРС}} R^2_{\text{ИЗС}} V^2_{\text{м РРС}}(T)}{P_{1\ \text{ИСЗ}} G_{1\ \text{ИСЗ}} P_{1\ \text{ЗС}} G_{1\ \text{ЗС}} R^2 V^2_{\text{м ЗС}}(T)}. \tag{8}$$

Let us estimate the value of X_1 on the example of using the 6 GHz band for transmitting signals from a ZS to ISZ and the 4 GHz band for transmitting from ISZ to ZS. For these bands, it is possible to take the following average values in (3):

$$P_1 = 10\ \text{Вт},\ G_{1\ \text{РРС}} = 10^4,$$
$$P_{1\ \text{ИСЗ}} = 20\ \text{Вт},\ G_{1\ \text{ИСЗ}} = 400,\ P_{1\ \text{ЗС}} =$$
$$= 10^3\ \text{Вт},\ G_{1\ \text{ЗС}} = 4 \cdot 10^5,$$
$$R_{\text{ИСЗ}} = 4 \cdot 10^4\ \text{км},\ R = 50\ \text{км}.$$

Then we have

$$X_1 = 2 \cdot 10^3 \frac{V^2_{\text{м РРС}}(T)}{V^2_{\text{м ЗС}}(T)}. \tag{9}$$

Even if we assume that

$$V_{\text{м РРС}}(T) / V_{\text{м ЗС}}(T) = 1,$$

then we obtain from (9) that the ratio of the power of interference to the power of the useful signal at the output of the receiving antenna of the ZS is by 33 dB higher than the value of such ratio at the output of the receiving antenna of the RRS. Consequently, there will be the same difference in the levels of noise in the channels caused by the interference. In real conditions, the difference will be still greater at any T, because with the main mechanisms of the appearance of interfering signals (diffraction and distant tropospheric propagation of radio waves) the relation

$$V_{\text{м РРС}}(T)/V_{\text{м ЗС}}(T) > 1.$$

2. The attenuation of the levels of interfering signals due to the DN of antennas is great, i.e., $F^2_{RRS}(\varphi) \ll 1$ and $F^2_{ZS}(\varphi_{ZS}, \Delta_{ZS}) \ll 1$. The mutual interfering effect between the RRS and ZS becomes noticeable only at small R_M, when it is possible to disregard the time-dependent changes in the levels of interfering signals and consider that their propagation takes place in conditions close to the free space conditions ($V_{M\ RRS}(T) = V_{M\ ZS}(T) = 1$). Assuming that the attenuation of the levels of interfering signals due to the antenna DN is identical under the effect of interference from RRS upon ZS and from ZS upon RRS, we shall find that the relation (6) and (7)

$$X_2(T) = \frac{P_1^2 G_{1\ \text{РРС}} R^2_{\text{ИСЗ}} V^2(T)}{P_{1\ \text{ИСЗ}} G_{1\ \text{ИСЗ}} P_{1\ \text{ЗС}} G_{1\ \text{ЗС}} R^2}. \qquad (10)$$

As was mentioned above, at $R \approx 50$ km for the frequency band of 4-6 GHz, $V(20\%) = 0.63$, $V(0.01\%) = 4.47 \cdot 10^{-2}$. Therefore, for the same values of P_1, $G_{1\ RRS}$, $P_{1\ ISZ}$, $G_{1\ ISZ}$, $P_{1\ ZS}$, $G_{1\ ZS}$ and R_{ISZ}, from (10) we have $X_2(20\%) = 8.10^2$, $X_2(0.01\%) = 4$. Consequently, even in the course of 0.01% of time, the ratio P_{2M}/P_2 is one-fourth of $P_{2M\ ZS}/P_{2\ ZS}$, although [3] sets the norm of 50,000 pW for the permissible value of noise due to the effect of interference in the course of 0.01% of time, while the permissible level of noise for ZS at a constant value of the ratio $P_{2M\ ZS}/P_{2\ ZS}$ must be at least less than 1000 pW.

The above figures indicate that the energy parameters of modern radio equipment are very far from optimal from the viewpoint of its EMS with ZS communication systems via ISZ, because the situation of interference and, consequently, the necessary territorial separation of RRS and ZS, are determined by the radiation of RRS no matter how they are arranged in relation to the ZS.

Of course, this situation cannot be considered justifiable. In fact, due to the special characteristics of the systems of communication via ISZ, the levels of useful signals at the inputs of ZS receivers cannot be increaseed substantially without a considerable impairment of the technical and economic indexes of these systems and impermissible increase of the level of interference from airborne transmitters to ground communication systems (see above). At the same time, it is quite possible to lower the energy parameters of radio relay equipment if the length of the RRL intervals is shortened appropriately. This will lead to a considerable improvement of the EMS conditions between RRS and ZS. For example, the lowering of the energy parameters of radio relay equipment operating in the 4-6 GHz band by 20 dB and the shortening of the lengths of the RRL intervals from 50 to 15 km results in the following values:

$$X_1=2{,}2V^2_{\text{м PPC}}(T)/V^2_{\text{м 3C}}(T);$$

i.e., this makes the interfering effect of the RRS on ZS and ZS on RRS approximately identical[1]. The necessary territorial spacing of the RRS and ZS will be reduced considerably in this case.

If the attenuation of the levels of interfering signals due to the antenna DN is great, then decrease of R_M will be defined by the relation

$$R_{\text{м}}\sim\sqrt{P_1G_{1\,\text{PPC}}}.$$

If the attenuation of the levels of interfering signals due to the antenna DN is small, the decrease of R_M will be even greater because the rate of decrease of the attenuation factor $V_M(T)$ with distance, for example in the zone of distant tropospheric propagation of radio waves, does not exceed 0.1 dB/km [8].

Interference Between the RRS of Territorially Spaced RRL and Between RRS of the Same RRL. Interference between RRL of approximately parallel direction can occur between the nearest RRS of these lines. Since a considerable attenuation of the levels of interfering signals is observed in these cases due to the DN of the RRS antennas, the interfering effect becomes noticeable only when the distances R_M between the RRS are sufficiently small. When R_M are small, it is possible to disregard the time-dependent changes in the power of the interfering signal P_{2M} and to consider that its propagation takes place in conditions close to the free space conditions.

Considering for the sake of simplicity that the energy parameters of two territorially spaced RRL are identical, it is easy to find that the ratio of the power of the interfering signal at the output of the receiving antenna of the RRS P_{2M} to the power of the useful signal $P_2(T)$ which is not exceeded in the course of T percent of time does not depend on the power of the transmitters and the gain factors of the transmitting antennas and is equal to

$$\frac{P_{2\text{м}}}{P_2(T)}=\frac{F^2(\varphi_1)F^2(\varphi_2)R^2}{R^2_{\text{м}}V^2(T)}, \tag{11}$$

---

[1] It should be considered that in the course of 0.01% of time the permissible noise level in the RRL channels due to interference is 50,000 pW, and in the course of 20% of time -- 1000 pW [3]. Therefore, the value of $X_2(0.01\%) = 4.4 \cdot 10^{-2}$ is quite permissible and is equivalent to the value of $X_2(20\%) = 2.2$.

where $F^2(\varphi_1)$, $F^2(\varphi_2)$ denote the attenuation of power of the interfering signal due to the DN of the transmitting and receiving antennas at the values of the azimuthal angles φ_1 and φ_2 at the location point of the source of interference and at the reception point.

Assuming that $P_{2M}/P_2(T)$ is equal to a certain permissible value $[P_{2M}/P_2(T)]_{\text{permissible}}$, we find the following from formula (11):

$$R_м(T) = \frac{F(\varphi_1)F(\varphi_2)}{V(T)\sqrt{[P_{2м}/P_2(T)]_{доп}}}\,(1), \qquad (12)$$

Key: 1. permissible

As was mentioned above, at $R = 50$ km in the frequency band of 4-6 GHz, $V(20\%) = 0.63$, $V(0.01\%) = 4.47 \cdot 10^{-2}$, therefore, from (12) we shall determine the minimum permissible values of $R_M(20\%)$ and $R_M(0.01\%)$ in km at which the norms for the level of noise in channels caused by interference are fulfilled:

$$R_м(20\%) = 79{,}5\,\frac{F(\varphi_1)F(\varphi_2)}{\sqrt{[P_{2м}/P(20\%)]_{доп}}}, \qquad (13)$$

$$R_м(0{,}01\%) = 1{,}12 \cdot 10^3 \times \frac{F(\varphi_1)F(\varphi_2)}{\sqrt{[P_{2м}/P_2(0{,}01\%)]_{доп}}}. \qquad (14)$$

Shortening the RRL intervals approximately to 15 km leads to the values of $V(20\%) \approx 1$, $V(0.01\%) = 0.143$ in the 4-6 GHz band [1]. Then, on the basis of formula (12) we obtain

$$R_м(20\%) = 15\,\frac{F(\varphi_1)F(\varphi_2)}{\sqrt{[P_{2м}/P_2(20\%)]_{доп}}}, \qquad (15)$$

$$R_м(0{,}01\%) = 1{,}05 \cdot 10^2 \times \frac{F(\varphi_1)F(\varphi_2)}{\sqrt{[P_{2м}/P_2(0{,}01\%)]_{доп}}}. \qquad (16)$$

It can be seen from the comparison of formulas (13), (15) and (14), (16) that, all other things being equal, by reducing the lengths of the RRL intervals from 50 to 15 km, it is possible to reduce the value of $R_M(20\%)$ to approximately one-fifth, and the value of $R_M(0.01\%)$ to one-tenth. Consequently, it is possible to increase substantially the density of the RRL network operating in the same frequency bands.

When the angles φ_1 and φ_2 are small, because of the small attenuation of the levels of interfering signals due to the DN of the antennas, the interfering effect of some RRL on other RRL could show itself even when the distances R_M between them are great. A typical example of such mutual interference in the case of a two-frequency plan is the interference between the first and fourth RRS of the same RRL, which makes it necessary to build the lines in a "zigzag" manner [6]. In this case, at $R_M \approx 3R$, the variance of random time-dependent changes in the level of the interfering signal is a decisive factor. In evaluating the relation P_{2M}/P_2 as a first approximation, it is possible to disregard the fading of the useful signal and write

$$\frac{P_{2M}(T)}{P_2} = \frac{1}{9} F^2(\varphi_1) F^2(\varphi_2) V_M^2(T), \tag{17}$$

where $P_{2M}(T)$ is the power of the interfering signal exceeded in the course of T percent of time. Considering that $P_{2M}(T)/P_2$ is equal to a certain permissible value $[P_{2M}(T)/P_2]_{\text{permissible}}$, from (17) we shall find the required value of the product

$$F^2(\varphi_1) F^2(\varphi_2) = \frac{9\,[P_{2M}(T)/P_2]_{\text{доп}}}{V_M^2(T)}. \tag{18}$$

As is shown in [7], normalized DN of antennas in the region of the main lobe can be approximated to a good approximation by the relation

$$F^2(\varphi) = \frac{1}{1+(\varphi/\varphi_0)^4}, \tag{19}$$

where φ_0 is one-half of the width of the main lobe with respect to half power. On the basis of formulas (18) and (19), we find the required values of the angles between the maximums of the DN of the antennas of the first and fourth RRS and the line connecting them under the condition that $\varphi_1 = \varphi_2 = \varphi$

$$\varphi = \varphi_0 \sqrt[4]{\frac{V_M(T)}{3\,[P_{2M}(T)/P_2]_{\text{доп}}} - 1}. \tag{20}$$

According to [6], $[P_{2M}(T)/P_2]_{\text{permissible}} = 10^{-7}$ for T = 20%. Lest us evaluate the values of $V_M(20\%)$ for RRL intervals of usual lengths ($R = 50$ km, $R_M = 150$ km) and shortened intervals ($R = 15$ km, $R_M = 45$ km). Let us assume that the line runs above a smooth spherical earch surface, and the height of the antennas h was selected in such a way that, with average refraction conditions, the receiving antenna is in the first interference maximum, i.e.,

$$h = \frac{R^2}{8a_э} + \frac{\sqrt{R\lambda_{PPC}}}{2}, \tag{21}$$

where $a_э = 8500$ km is the value of the equivalent radius of the earth with average refraction conditions. At $R = 50$ km and $R_M = 3R = 150$ km, the appearance of the interfering signal will be caused by distant tropospheric propagation of radio waves. The value of $V_M(20\%)$ depends on the equivalent distance $R_{э.м} \approx 3R - 2\sqrt{2a_э h_1}$ and at R = 50 km for the frequency band 4-6 GHz, according to [6], we have $V_M(20\%) = 7.07 \cdot 10^{-3}$ (-43 dB).

If R = 15 km, then $R_M = 3R = 45$ km, and the interfering signal occurs chiefly due to the diffraction of radio waves around the earth's surface during increased refraction. For the smooth spherical surface of the earth, at the values of h defined by formula (21), and typical parameters of statistical distribution of the vertical gradient of the dielectric permeability of the air, according to the method of [6], we shall find that $V_M(20\%) = 0.316$ (-10 dB) for the 4-6 GHz frequency band.

Assuming in (20) that

$$[P_{2M}(20\%)/P_2]_{доп} = 10^{-7},$$

we shall obtain the required values of the angles $\varphi = 1.59\ \varphi_0$ at R = 50 km and $\varphi = 4.26\ \varphi_0$ at R = 15 km. Consequently, in order to maintain the same value of $[P_{2M}(20\%)/P_2]_{permissible}$ when the intervals are shortened, the necessary value of angles φ is 2.7 times greater than for the intervals of usual lengths. Since the length of the intervals in the above example was shortened 3.3 times, the required value of the relation $[P_{2M}(20\%)/P_2]_{permis}$ will be ensured at approximately the same linear deviation of the location of the intermediate RRS from the arc of the great circle passing through the first and fourth RRS as in the case of intervals of usual lengths.

It should be mentioned that the assumption made in the above example regarding the absence of fading of the useful signal places the case of intervals of usual length in more favorable conditions. In fact, at large R, due to increased variance of random time-dependent changes of P_2, the probability of exceeding $(P_{2M}/P_2)_{permissible}$ will be determined not only by random growth of P_{2M}, but also by random decrease of P_2.

Conclusion. The above evaluations show that by reducing the lengths of RRL intervals and by lowering the energy parameters of radio relay equipment to values ensuring the necessary quality indexes of the line channels, it is possible to improve the conditions of electromagnetic compatibility of RRL with other communication systems operating in shared frequency bands as follows: 1. Practically complete elimination of the interfering effect of RRS on airborne receivers of communication systems using ISZ on the geostationary orbit, and, consequently, elimination of limitations for the configuration of RRL construction. 2. Considerable reduction of the interfering effect of RRS radiation on the receivers of the ZS of communication systems using ISZ to a level commensurable with the interfering action of radiation of the ZS on the RRS receivers, and, consequently, the requirements on the frequency and territorial spacing of RRS and ZS. 3. A considerable lowering of the interference level between territorially spaced RRL, which makes it possible to increase by many folds the density of the RRL network operating in the same frequency band.

The above possibilities of improving the EMS conditions are particularly important for rational utilization of the 2-8 GHz frequency band, where the conditions for the propagation of radio waves are most favorable.

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USSR

UDC 621.397.837

COMPLEX DETERMINATION OF TOLERANCE FOR THE PARAMETERS OF A COMPLETE COLOR TELECASTING CHANNEL

Moscow ELEKTROSVYAZ' in Russian No 9, Sep 78 pp 22-30

[Article by N. G. Deryugin and A. K. Kustarev, published as a matter for discussion, submitted 17 Mar 1978]

[Text] Introduction. In the process of operation, the parameters of the color television channel (TsTV) from the source of the program up to and including the television receiver are bound to deviate from their rated values. Some of them, for example, colors of the glow of the picture tube luminophores, have deviations which are static in nature and occur in the process of production. Others change in the process of transmission due to unstable operation of the equipment. Thus, the parameters of the color television channel can be considered as random values which have static or dynamic deviations from the rated values.

Changes in the channel parameters lead to inaccurate reproduction of color in the television image and to the appearance of other distortions which impair its quality. In order to ensure a definite quality of the color image, random deviations of the channel parameters must be within certain limits. Such limits, i.e., tolerance for possible deviations of various parameters from their rated values, are established as a result of a compromise between the quality of the image and the complexity of the equipment which must ensure operation with a prescribed tolerance.

In many works some of which are discussed in [1], tolerances are established without consideration of both probabilistic characteristics of random statistical and dynamic deviations of the parameters from the rated values, and simultaneous appearance of various distortions. Very often tolerances are established on the basis of production possibilities of manufacturing TV equipment and the experience of its operation [2]. In some works, for example, those discussed in [3], attempts are made to work out various generalized criteria for the quality of the color image in which various distortions with known values are present. But these works are far from completion and their results cannot be used for the determination of tolerances.

Thus, up to now there is no single approach to the process of normalization of the parameters of the TsTV channel. In this connection, general principles have been developed for determining tolerances with consideration for possible simultaneous changes in all parameters of the channel.

All types of distortions in the color image and, accordingly, of the parameters causing these distortions are divided into three groups. The manifestation of the distortions of individual groups and their perception by the viewer are different. Due to this, different approaches are used for establishing tolerances for the parameters of the three groups. This made it possible to simplify the complex solution of this problem.

The concept of the grouped channel parameter has been introduced. It is an aggregate of various parameters and characteristics of the channel whose deviations from the norm, regardless of the place of their orgination, lead to the appearance of distortions of one kind in the TV image. An overall tolerance for the entire channel is determined on the basis of experimentally established permissible values of distortions for each grouped parameter. Then, this tolerance is distributed over individual sections of the channel with consideration for the technical and economic factors.

The Composition of the TsTV Channel and the Quality of Its Output Image. In setting the norms for the parameters of the channel, we shall proceed from the fact that the quality of the color image on stationary color television receivers must correspond to the subjective evaluation of no less than 4 points, and in portable sets -- not any lower than 3 points according to the 5-point scale of the MKKR [International Radio Consultative Committee], 5 being the highest evaluation. This is an acceptable compromise between the desire to ensure a high-quality image and the requirements for the complexity and costs of the equipment.

A real TsTB channel may contain various numbers of sections (Figure 1): ASK -- studio equipment complex; VTP -- telecasting transmitter; P -- receiver; NLS -- land communication line (cable, radio relay); TP -- television transmitter; SLS -- satellite communication line; PU -- receiving device; R -- low-power repeater. The simplest TsTV channel consists of three sections, namely, ASK-VTP-P. It is possible to have a case when a TsTV channel contains nine sections (ASK-NLS-TP-SLS-PU-NLS-VTP-R-P). The ASK-VTP-P sections are the main ones, while others ensure only the relaying of a complete color TV signal.

It is natural that the quality of the color TV image at the output of a TsTV channel will depend on the composition of the channel. The more relay sections in the channel, the more distortion there is in the video signal, and, consequently, the more inferior is the quality of the image. If attempts are made to ensure the quality of the output image of the most complex channel corresponding to a stationary receiver (not any lower than 4 points), then the tolerances will be very severe, which will require the development of expensive equipment. Moreover, the quality of the output image of a channel without relay sections will not be realized by TV receivers.

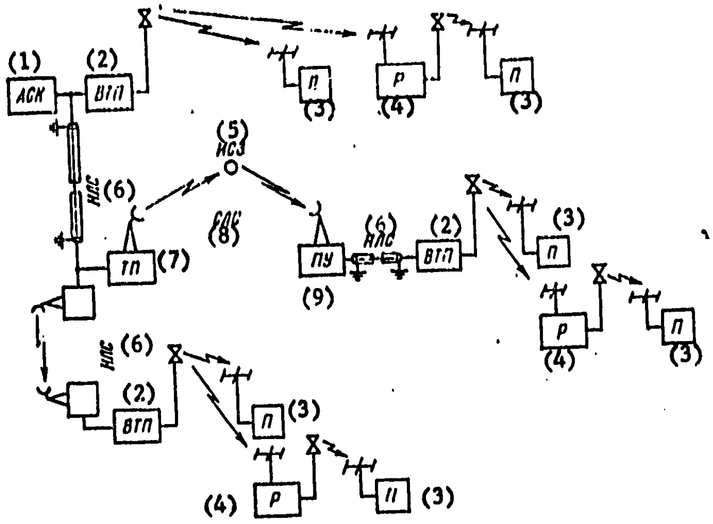

Figure 1

Key: 1. ASK
2. VTP
3. P
4 R
5. ISZ
6. NLS
7. TP
8. SLS
9. PU

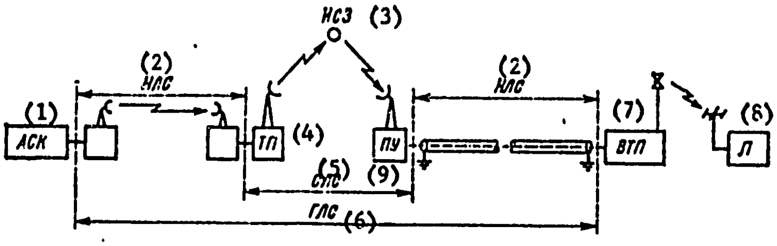

Figure 2

Key: 1. ASK
2. NLS
3. ISZ [artificial earth satellite]
4. TP
5. SLS
6. GLS [hypothetical communication line]
7. VTP
8. P
9. PU

Therefore, when establishing tolerances, it seems practical to proceed from the presence of a hypothetical TsTV channel of average complexity (Figure 2). In it, the hypothetical communication line GLS may consist, for example, of a land radio relay or cable line of a total length of 2500 km and a hypothetical standard satellite communication line [4]. In this case, the quality of the output TV image of a channel more complex than the hypothetical channel will be somewhat inferior than the quality set for the corresponding types of receivers, and in the case of a simpler channel, it will be ensured with a margin of safety.

Thus, tolerances for the parameters of a TsTV channel must be selected in such a way that, for a certain percentage of time (let us say, 80%), the quality of the color image of not less than 4 points and 3 points would be ensured at the output of the hypothetical channel for the stationary and portable TV receivers, respectively.

Since the channel is calculated from the condition of obtaining a quality of 4 points on stationary receivers, a quality of 3 points will be obtained for portable receivers only at the expense of great tolerances for the parameters of the receiver. Therefore, first it is necessary to establish tolerances for the parameters of the TsTV channel with a stationary receiver, and then tolerances for the parameters of a portable receiver.

Classification of Distortions in a Color Television Image. Distortions of the color TV image may be divided into two classes which we shall term conventionally as achromatic and chromatic.

Acromatic distortions show thenselves in the color image in the same way as in the black-and-white TV image and are connected chiefly with errors in the scanning and synthesis of the image. This group also includes brightness noises. Various achromatic distortions, their causes and possible places of their origination are shown in Table 1. Chromatic distortions, in turn, can be divided into two characteristic groups which are chiefly connected with errors in color reproduction in small and large areas of the image. Small areas can be conventionally considered to be sections with a minimum size of up to 8-10 image elements, and large areas -- sections of over 8-10 elements.

We shall term color distortion of small image areas as heterogeneous distortion. Although they show themselves as changes in the color, these distortions should not be treated as disturbances in the fidelity of color transmission. The concept of the fidelity of color transmission itself refers, strictly speaking, only to the reproduction of color in large sections of the image. Heterogeneous distortions are perceived by the viewer not as inaccurate reproduction of colors, but as various defects leading to the deterioration of the overall quality of the image analogous to achromatic distortions. These are chrominance noise, color edging, etc. This also includes drawn out prolongations which could occupy large areas, but, by the nature of their perception, belong to heterogeneous distortions. The latter show themselves in a color picture independently from one another and are dynamic in nature. The data on various distortions are summarized in Table 2.

Table 1

No	Types of achromatic distortions (grouped channel error)	Overall Channel parameters whose changes cause distortions	Nature of distortions	Sections of Chanel where parameter deviations are possible
1	Coordinate	Scanning nonlinearites, etc	Static	ASK, P
2	Disturbances of interlaced scanning	Asymmetry of interlaced scanning	Dynamic	
3	Uneven sharpness over the scanning pattern field	Aperture Distortions of the camera and picture tubes	Static	
4	Repeated images	Matching, Echo signals	"	ASK, GLS, VTP, P
5	Black-and-white dots and strokes	Pulse interference	Dynamic	
6	Brightness noise	Ratio of Brightness signal to fluctuation noise in 0.3-6.0 MHz band	"	
7	Moving low-frequency interference	Ratio of signal to background noise	"	
8	Unsatisfactory reproduction of small details and sharp brightness changing	Nonuniformity of AChKh [amplitude-frequency characteristic] in 0.5-6.0 MHz frequency band	"	
9	Fine grid	High-frequency interference	"	
10	Gradational	Nonlinear distortion coefficient of the brightness channel	"	

Distortions of color in large areas show themselves as disturbances in the fidelity of color transmission. Due to various causes, colors in the image could change in different ways, and the resulting distortions in color transmission may intensify or weaken, or even compensate one another.

The grouped parameters whose deviations from the rated values cause distortions in color transmission are listed in Table 3. Distortions in color transmission arise as a result of changes in the parameters and characteristics of the transmission channel and deviations from the rated values of color signals at various points of the channel.

The TsTV channel has two main groups of signals which correspond to the color coordinates in two color systems, namely, the systems of the receiver and the transmission channel. Consequently, it is possible to isolate two grouped parameters. The first one includes various types of disturbances leading to independent changes in the signals corresponding to the color coordinates R, G, B in the system of the receiver, and the second parameter

Table 2

Types of heterogeneous color distortions (grouped channel error)	General channel parameters whose changes cause distortions	Sections of channel where deviations of parameters are possible
Chrominance noise	Ratio of the brightness signal to fluctuation noise in the chrominance channel	ASK, GLS, VTP, P
Discontinuous colored fringe	Differential phase	Same
	Differential gain	"
	Fluctuation noise in the chrominance band	"
	AChKh nonuniformity in the chrominance band	"
	Mismatch of VCh [high frequency] characteristics of predistortion and correction	ASK, P
Colored drawn out prolongations	Differential phase	ASK, GLS, VTP, P
	Transient characteristic in the area of low and medium frequencies	Same
	Mismatch of predistortion and and correction with respect to video frequency	ASK, P
Colored edging	Inaccurate matching of rasters	ASK, P
	Transient characteristic in the area of high frequencies	ASK, GLS, VTP, P
	Timing discrepancy between the brightness and chrominance signals	Same
Partial or total absence of color in small image areas	Transient characteristic of the chrominance channel (color sharpness)	ASK, P
Difference in the reproduction of adjacent lines or groups of lines	Mismatch of the direct and delayed signals	Same
	Difference in the sensitivity of the heads of the video tape recorder	ASK

leads to changes in the signals corresponding to the color coordinates D_R, Y, D_B in the system of the transmission channel. Changes in the signals cause distortions which are dynamic in nature.

Table 3

No	Grouped channel parameter	General channel parameters whose changes cause distortions in color transmission	Nature of distortion	Sections of channel where deviations of parameters are possible
1	Color coordinates R, G, B	Amplitude of the signal of primary color	Dynamic	ASK
		Amplitude of gamma-predistorted signal of primary color	"	"
		Value of protective interval (level of black)	"	ASK, P
		Transmission Characteristics of channels of primary colors from light to light	"	"
		Nonuniformity of color over the raster field	Static, dynamic	ASK, GLS, VTP, P
		Spectral Characteristics of the sensor of main signals	Static	ASK
		Primary colors of receiving tube	"	P
2	Color coordinates D_R, Y, D_B	Amplitude of the brightness signal	Dynamic	ASK, GLS, P
		Amplitude of the color difference signal	"	ASK, P

Changes of such parameters as the primary colors of the receiver and the spectral characteristics of the sensor of color signals cause distortions in color transmission which are, chiefly, static in nature. It is possible to consider that deviations of these two parameters result in constant errors in the reproduction of all colors in the image (but different for different receivers and sensors) with the exception of the reference white color. The latter will not change if the correct color balance is maintained both in the receiver and in the sensor of the signals.

It is assumed that the color system of the receiver is realized in the sensor of signals. If it is not so, then it is necessary to examine the deviations of both spectral characteristics and output signals from the rated values in the coordinate system of the sensor and to introduce a third grouped parameter.

Theoretical Study on Separate Effects of Changes in the Parameters of the TsTV Channel. When breaking the overall tolerance for a grouped parameter into individual parameters, it is necessary to know what distortions occur in the TV image due to changes in only one parameter when all remaining parameters are unchanged. It is relatively simple to study this theoretically for the parameters whose deviations from the rated values cause distortions in color transmission (Table 3). Distortions of colors occurring during various changes within prescribed limits of some parameter of this group can be represented in the form of spatial areas in a color space, and the possible changes in the chrominance can be represented in the form of variation zones in the chrominance chart [5, 6]. It is sufficient to plot such variation zones for several (reference) chrominances.

The effect of changes in individual parameters causing herterogeneous distortions can also be studied theoretically. However, in this case, it is more expedient to represent the obtained computation data not in the form of changes in the chrominance, but in the form of distortions of various test signals (for example, in the form of tolerance zones for transient, pulse, and other characteristics).

The determination of permissible distortions of the color TV image can be done only experimentally. Since the quality of the image depends on the presence of distortions of all three groups in it (achromatic, heterogeneous color distortions, and distortions in color transmission), permissible distortions should be determined when they show themselves simultaneously in the image. However, it is very difficult to do this due to a large number of possible combinations of the values and types of various distortions. It is more realistic to find permissible distortions separately for each group.

Since the distortions of the three groups show themselves in the TV image in in different ways, the viewer, psychologically, perceives them separately. For example, achomatic and heterogeneous color distortions are perceived by the viewer as various defects in the image, and distortions in color transmission -- as incorrect reproduction of colors which he evaluates by the reproduction of colors familiar to him (for example, the color of flesh, the color of vegetation, etc).

Simultaneous manifestation of distortions of all three groups can be estimated approximately if the criteria for the evaluation of the quality of the image in determining permissible distortions are somewhat higher than those accepted above for the resulting quality of the image. Instead of the evaluations 4 and 3 for stationary and portable sets, it is possible to take the evaluations of 4.2 and 3.5 points, respectively.

Permissible values of achromatic distortions in a color image can be established by the same method as for the black-and-white image, or to borrow them directly from the experience of black-and-white television.

Permissible values of heterogeneous color distortions are found experimentally separately for each type of distortion (for each grouped error shown in Table 2) during simultaneous changes in all parameters causing this distortion, i.e., which make up the grouped parameter. For example, the permissible value of the distortion "discontinues colored fringe" (Table 2) must be established when the following overall parameters of the channel deviate from the norm simultaneously: differential phase, differential gain, fluctuation noise in the band of the chrominance signal, irregularities in the AChKh in the band of the chrominance signal, and the mismatch of the chatacteristic of high-frequency predistortion and its correction. Tolerance values for the appropriate overall parameters of the channel are obtained directly from the experimental data on permissible distortions.

Permissible distortions of color transmission can be determined through subjective evaluation of the quality of color transmission by the viewers on real subjects when various distortions of colors are introduced into the image. In order to create them, it is not necessary to change simultaneously all of the overall parameters of the channel listed in Table 3. For example, distortions in color transmissions can be created by linear transformation of three color signals [7]. During such transformations, there will occur changes both in the chrominance and in the brightness of the image. Changes in the overall brightness of the image. Changes in the overall brightness of the image can be disregarded because, firstly, it is not the goal of television transmission to reproduce the absolute value of the brightness of the scenery and, secondly, changes in the brightness during real transmission progress slowly and can be eliminated to a certain degree by the viewer by means of the control devices which are at his disposal.

As a result of subjective evaluation of the quality of color transmission, permissible variation zones must be obtained on the chrominance chart for the selected reference chrominances and for each quality class. With any changes in the parameters leading to the appearance of distortions in color transmission, each of the reference chrominances must not go beyond the limits of the zone established for it. It is sufficient to find the zones of permissible variation for four points of reference chrominances, the reference white color and chrominances which are close to the chrominances of the primary colors of the receiver. Such zones for two evaluations of quality were determined experimentally [8,9].

Determination of Tolerances for the Overall Channel Parameters. As tolerances for the overall parameters 1-5 of Table 1, it is possible to take tolerances for analogous parameters of black-and-white television. Tolerances for the parameters 6-10 must be refined with consideration for the peculiarities of color television.

Tolerancesfor each of the grouped parameters of Table 2 and parameters 6-10 of Table 1 are established, as was mentioned above, through experimental determination of permissible distortion. The combined effect of all grouped parameters causing heterogeneous color distortions is taken into consideration by using the evaluations of 4.2 and 3.5 units as a criterion of the image quality during a change in only one grouped parameter.

During simultaneous independent changes in the overall parameters of group 1 of Table 3, the values of color signals E_R, E_G, and E_B will fluctuate. As a result of this, the point of the color reproduced on the screen of the picture tube will fluctuate in the color space within the limits of a certain spatial zone. If we assume that the changes of the three color coordinates follow the normal laws, then the surface of equal probability density in the color space limiting the zone within which the fluctuating point of the given color is located with prescribed probability will be an ellipsoid. This ellipsoid of scattering can be easily calculated for prescribed tolerances for changes in the grouped parameter and the probability of the penetration of the point of wrong color within the ellipsoid. The major axes of the ellipsoid are parallel to the axes of coordinates R, G, B. Analogous computation for the grouped parameter 2 of Table 3 will also yield an ellipsoid of scattering in the color space, but with major axes directed along the axes of coordinates D_R, Y, D_B.

The spatial scattering zone of the color point as a result of simultaneous independent changes of both grouped parameters can be found by convoluting the two determined distribution laws. The resulting ellipsoid obtained through convolution is projected onto a unit plane of the color space, which gives the zone of the possible variation of chrominance in the chrominance chart in the form of an ellipse of equal probability density. This operation is performed for all four reference chrominances. The summation of various errors affecting the fidelity of color transmission is shown in Figure 3.

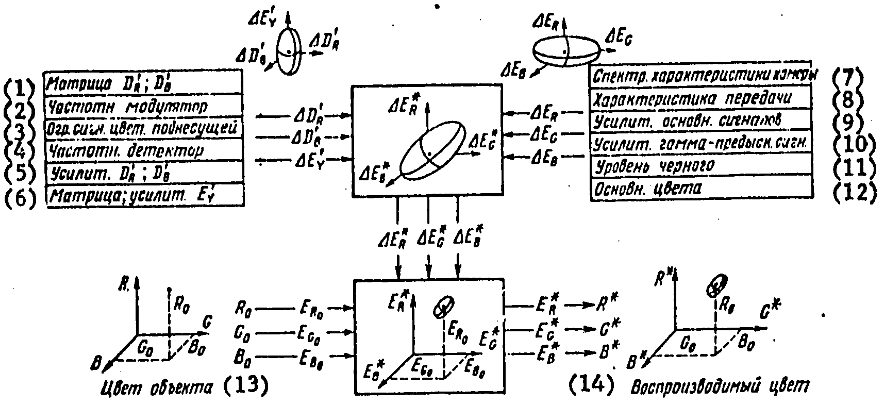

Figure 3

Key:
1. Matrix
2. Frequency modulator
3. Limiter of signal of color subcarrier
4. Frequency detector
5. Amplifier
6. Matrix: amplifier
7. Camera spectral characteristics
8. Transmission characteristic
9. Amplifier of fundamental signals
10. Amplifier of gamma-predistorted signal
11. Level of black color
12. Primary colors
13. Color of the object
14. Reproduced color

The operations described above make it possible to find the distribution of the resulting chrominance error, i.e., the zone of possible chrominance variation for the prescribed tolerances for grouped parameters. However, in order to determine the tolerance, it is necessary to solve an inverse problem, namely, to break down the resulting error into grouped errors. This can be done by the trial-and-error method when the resulting zone of possible chrominance variation is found having been given the tolerance for the grouped parameters. Tolerance for changes in each of the three color coordinates (signals) for two grouped parameters of Table 3 must be selected in such a way that the ellipses of possible chrominance variation for all four reference chrominances would not go beyond the limits of the established zones of permissible variation and would be as close to them as possible.

The established tolerances for grouped parameters are broken down in an analogous manner into individual general parameters. In this case, the data on the effects of changes in individual parameters on color transmission are used.

Breaking Tolerances into General Parameters by the Sections of the Channel. It is mathematically difficult to perform this. It is possible to solve an inverse problem, namely, to determine the resulting tolerance by the known tolerences for invividual sections. The summation laws of tolerances can be found theoretically or on the basis of experimental data. Tolerances for individual sections are established by selection in such a way that the obtained resulting tolerance would coincide with the overall tolerance for the entire channel. In so doing, it is necessary to consider the economic factor, for example, a less severe tolerance should be prescribed for a television receiver, and a more severe tolerance for ASK.

The calculation of resulting tolerances for heterogeneous color distortions are often done by empirical arithmetic or quadratic laws of summation of distortions of one kind. In individual instances, both the arithmetic and quadratic summations are used("intermediate" law), i.e., the so-called 3/2 law. For differential phase distortions, the author of [10] suggested to divide by $\sqrt{3}$ the results of the computation of the overall tolerance with the use of the quadratic law.

Table 4

Закон суммирования (1)	[illegible] (4)			
	АСК (5)	ГЛС (6)	ВТП (7)	П (8)
(2) Арифметический	±2	±4	±3	±6
3/2	±3	±6,5	±4	±9
(3) Квадратичный	±4	±8	±5	±11

Key: 1. Summation law 4. Tolerances for the differential phase, degrees,
2. Arithmetic for channel sections 6. GLS
3. Quadratic 5. ASK 7. VTP 8. P

Table 4 gives an example of the results of breaking the overall tolerance into a differential phase (±15 degrees) by the sections of the TsTV channel for various summation laws.

Table 4 shows the dependence of the values of tolerances for individual sections of the channel on the summation laws. In this connection, it is necessary to continue work on the determination of summation laws for various distortions.

The summation of tolerances for parameters affecting color transmission can be done by the quadratic law, since it was assumed above that the distribution of errors from the fluctuations of the parameters of Table 3 at the channel output is normal. This law can also be used in determining the resulting tolerance of a section by the prescribed tolerancesfor individual assemblies, units, and other elements of the section.

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CSO: 5500

ITALY

'TALKING' COMPUTER DEVELOPED BY CSELT OF TURIN

Milan L'EUROPEO in Italian 24 Nov 78 pp 154-156

[Article by Giuliano Ferrieri: "The Computer Takes the Floor"]

[Text] Turin, November--"It sounds like a German voice," one person says. Another says, "Not at all; I say it's the voice of a southerner." Still others "Disturbing." "Inhuman." "Attractive but disturbing."

These are some of the comments gathered at random among a group of persons who were listening to, for the first time, the voice of an electronic calculator. It is a talking computer, reading the written word. The voice is warm, full; it no longer has the monotonous tone that characterized the first talking machines attempted (except for some syllabic interruptions and brief periods of "confusion" in the vowels). But what is striking is that the machine has within itself, in an internal storehouse, hundreds of "sounds," which as such are neutral. But it is he, the computer, who gives tone, meaning and warmth to the sentences through a series of mechanical operations. The raw material in the calculator comes from man. It is the machine that makes the dialog "human." And therefore, as one hearer said justifiably, it is "disturbing."

The calculator was developed by Turin's CSELT (The Center for Telecommunications Research and Laboratories, one of the forward-looking Italian research centers) and it was studied by a multidiscipline team headed by electro-acoustic engineer Giulio Modena. Is this a first? Is it a toy or an instrument with a future? How does the talking calculator work? What problems were solved in order to develop it? And what will its uses be?

Naturally, there is nothing new in the world. In ancient Syracuse, a talking statue warned the people in times of emergency; and, after all, today in many nations the telephone alarm advises us with a voice ("it is 7 o'clock, sir") without the need for an operator on the other end of the line. But in both these cases there is a "trick": Within the statue of Ephesus a man was hidden who was employed by the tyrant Dionysius to frighten his subjects; the voice on the telephone alarm is merely recorded.

In 1791 a Hungarian baron, von Kempelen, invented a talking machine that tried to reproduce the vocal cords, the lungs and man's oral cavity with bellows and wires. In 1937, the "mechanical speaker" was built by Riesz and in 1939 the Voder voice demonstrator was built by Bell Laboratories. But in each of these cases it is still man who makes the machine emit the desired sounds and "words"--by controlling the air stops in the Von Kempelen apparatus with his fingers and operating the others electrically through a keyboard and pedals.

The scene changed radically when in the postwar period science was able to utilize electronic calculators. To break down and store syllabic groups was relatively easy and machines of this type multiplied. But as the proverb says, "The way out is easiest." The difficulties began after the threshold was crossed. Machines that read letters and translated them into sounds not only produced a rumbling monotone that was tiresome and annoying (this would be the least of the problems) but had the defect of not resolving the elementary problems of understanding the message: "If I hear DIAMANTINEHATANTI," Professor Ceccato says jokingly, "I don't understand whether the reference is to an adulterous woman or one who has many precious stones..." These limitations bordered on the "games department" of studies on talking machines and some decades passed without revolutionary developments in the sector.

As we said, the main characteristic of the new machine is its ability to give phrases cadence and "tonality," for example, to take into account the proper degree of suspension in a question which is to come later. How was this arrived at?

"The preliminary work was that of the linguists," explains Engineer Modena (and he mentions Professor Bertinetto, of the University of Turin), "Who studied for us the rule of structure of the Italian language. They established that, from one point to the following point, a phrase with a certain number of syllables, so many punctuation elements (commas, etc) and certain pauses of separation between words, necessarily involves a kind of 'tone' and 'breath' that are characteristic of the melodic progression. After the linguists (and naturally also physicians and psychologists) finished their work, it was up to us, the experts in electroacoustics and in calculators, to translate their results into numerical values, the only ones the computer understands."

In other words, the talking computer scans with lightening speed (infinitesimal fractions of a second are enough) the entire "nature" of a sentence from beginning to end, the punctuation points and breaks between the words. The result of the calculation automatically determines that the computer will choose, from among a certain number of alternatives, the right tonality with which to proceed with the reading. Regarding reading per se, this is done with "stored" sounds (the first part, resolved some time ago, of the problem. Even here the Turin machine, however, has innovations, in the sense that the current principle of syllabic division was replaced by stored sounds based on groups called "diphonics." These number 150 and each is composed of a vowel and one or more consonants preceding it.)

This is certainly an Italian first which outstrips the excellent predecessors (carefully studied by CSELT which mentions them with respect) such as the "mechanical reporter" by Ceccato at the University of Milan, and the apparatus realized in the University of Padua electronics laboratory. Is this also a world first? "We are alined on the world scale," says engineer Pierino Tonetto, CSELT co-director. He adds, "at the better end of the scale." This is considerable for a nation with Italy's research deficit, even though it is only experimental. But as the English say, it is also an "understatement": Those who have seen the "best" of the American navy and air force (which are giving careful attention to these studies) maintain that the Turin talking machine is better.

Within limits. Because it has them. The CSELT computer needs, for example, a "prepared" text with little indicators that coach it (otherwise it would read all the words flat). Improvements can be made, and this is already done in connection with the fluency of reading tones. It does not yet have a scanner for the analysis of any written text (this will come). And naturally it is not being produced commercially (but the "exploitation" of the prototype is not a matter that concerns CSELT, which is a research center).

To what use will it be put? Emotionally, the advantage that strikes one at first is that of freeing the blind from the slavery of Braille. Those who cannot see can buy a book, a weekly magazine, a daily newspaper, and put it into the machine to hear its contents.

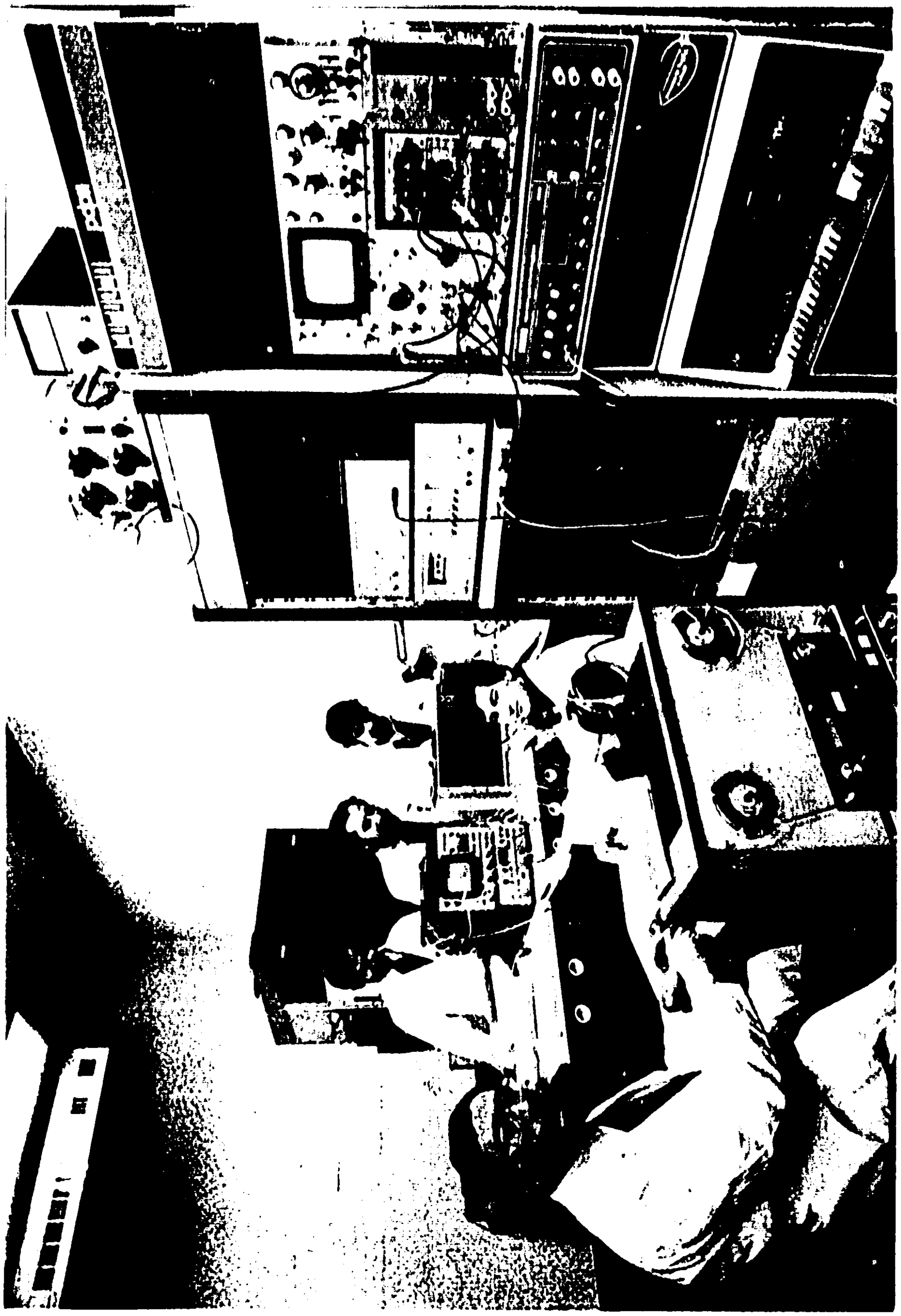
In less dramatic terms, but economically and numerically much broader, the talking calculator will be useful to us all, particularly through employment over telephone lines: For bank reports, on the weather, on daily news (which can be obtained from a telephone number it is true, but through the use of recorded tapes that are replaced after intervals of time; instead, the calculator would instantly include every new event and would be able to continually give up-to-date, clear replies at the precise instant when the user calls upon it).

Furthermore, the new computer will give us a verbal report of information contained in the encyclopedia and the library and reports from data centers where other macroscopic computers function. Today all these reports are handled by the "high priests of the calculators" and they can be collected by the small number of the elite who possess a "terminal" on whose screens the reports appear. In the future, with the substitution of the new talking terminal for the textual terminal, a few coins will be sufficient so that anyone, from a small town and without going elsewhere, can have available to him the most minute and up-to-date information from the great university centers of knowledge (at least in theory; in practice, certainly, the problem of "coded" reports will have to be solved. These are the reports that rightly or wrongly are withheld from everyone so that they can be reserved for privileged categories.)

An Additional Service

And what about the ethical aspect, the perennial (but always dramatic) question of the danger that the machine will "replace" man rather than serve him? This was raised recently at Paris in an international symposium of specialists on the subject "The Computer and Data Control." We dealt with the problem separately, in a talk with Professor Ceccato which goes beyond the Turin calculator.

But as far as the CSELT machine is concerned, it must be said immediately that the question has less weight. This is not a question of the atom bomb or genetics, which can be used for good or for evil (after all, that line is also valid for the invention of the knife) but for an important and limited discover. Tonetto says, "We plan only to supply the most useful and least costly services that will multiply contacts between men." It is significant that the Turin machine evolved, beginning with the teletype, with techniques that limit the parameters of memorization to the indispensable (and "poor memory" means use of small and therefore cheap calculators). Engineer Scagliola, another source in the group, adds: "At first information was transmitted orally; it multiplied with the advent of printing. That the calculator today can make the page talk cannot frighten people: On the contrary, it can only bring them closer together."



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