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On the Physical and Communication Properties of a Thermodynamical Communication Channel

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This paper deals with the investigation of relations between the physical and communication properties of the communication channel provided that the source and the receiver of information are realized as a thermodynamic system of two bodies with a transfer of information developing betweem them by means of their thermal contact. At the same time relations between thermodynamic and information-theoretical properties at such physical realization of the transfer channel are found and a discussion of its optimization from the viewpoint of the amount of transferred information and magnitudes of physical changes developed during this transfer is outlined.

INTRODUCTION

Mathematical model of the transfer channel ([1] Chapt. 6) may have various physical realizations. The individual states of the source and the receiver of information are generally realized as the physical states of physical systems allotted to them, on which physical random variables, denoted as $\tilde{f}_1$ and $\tilde{f}_2$, with certain probability distributions are defined. If an information between the source and receiver is to be transmitted, it is necessary that a certain statistical linkage should exist between the random variables $\tilde{f}_1$ and $\tilde{f}_2$. The said linkage is given mathematically by the probability distribution $\mathscr{P}$ of random variable $\tilde{f}_1$ as well as by a set of conditional probabilities representing the elements of a so-called transfer matrix R ([2] p. 33) and physically realized by means of a set of transfer signals creating mutual interaction between the source and the receiver of information.

Let us denote the element of probability distribution $\mathscr{P} = [p_1, p_2, \ldots, p_N]$ or transfer matrix R by symbol p_i or $r_i(j)$, respectively. If we confine ourselves to the discrete random variables $\tilde{f}_1$ and $\tilde{f}_2$, the magnitude of statistical linkage (mean amount of information contained in random variable $\tilde{f}_1$ about the random variable $\tilde{f}_2$) is within the framework of information theory given by the expression*

* We shall use for the information the nit (natural digit) units. See e. g. [2], p. 33.

$$(1) \qquad I(\tilde{f}_1, \tilde{f}_2) = \sum_{i,j} p_i r_i(j) \log \frac{r_i(j)}{q_j},$$

where

$$q_j = \sum_k p_k r_k(j).$$

The transfer signals are, of course, also physical objects being described by a certain set of physical data. By their sending and receiving the physical situation of the source and the receiver of information may be generally changed, which may cause a certain distortion of the transfer signals, and therefore also a change of informational parameters of the communication channels. This distortion is often of principial character and leads to certain basic boundaries of information-theoretical paramers of communication channels. Therefore, it is very important to choose for a certain communication channel its appropriate physical realization. The effects caused by a physical realization of the communication channel form a background of communication, the influence of which is necessary to be determined by the complex description of a certain communication process.

In this paper we shall deal with the determination of mutual relations between the information-theoretical properties of a communication channel and the physical properties of its physical realization. We shall start with a general description of the physical probability systems representing the physical systems of physical realizations of communication channels.

1. PHYSICAL REALIZATION OF THE PROBABILITY SYSTEMS

General physical probability system, being denoted by $\Sigma_f^{(1)}$, is able to assume one state from the measurable space of physical states $[S^{(1)}, \mathfrak{S}^{(1)}]$. On the σ-algebra $\mathfrak{S}^{(1)}$ a probability measure $\mu_f^{(1)}$ is given and on a set of physical states $S^{(1)}$ a physical random variable $\tilde{f}_1$ is defined whose values let be from the set $S_f^{(1)}$.

Physical probability system $\sum_f^{(1)}$ is determined by an ensemble of the following data

$$\Sigma_f^{(1)} = \{S^{(1)}, \mathfrak{S}^{(1)}, \mu_f^{(1)}, \tilde{f}_1\}.$$

Let us consider another physical probability system determined by an ensamble of the data

$$\Sigma_f^{(2)} = \{S^{(2)}, \mathfrak{S}^{(2)}, \mu_f^{(2)}, \tilde{f}_2\}.$$

The measure of the statistical linkage between the random variable $\tilde{f}_1$ and random variable $\tilde{f}_2$ which determines the magnitude of entropic linkage [3] between physical probability systems $\Sigma_f^{(1)}$ and $\Sigma_f^{(2)}$ is given by the information $I(\tilde{f}_1, \tilde{f}_2)$, being in case of discrete random variables determined by the formula (1).

Taking into consideration a close connection of the information-theoretical entropy and the physical entropy, it is justifiable to consider the quantity $I(\tilde{f}_1, \tilde{f}_2)$

as a measure of entropic dependence of the physical random variables $\tilde{f}_1$ and $\tilde{f}_2$.
For stochastically independent physical random variables $\tilde{f}_1$ and $\tilde{f}_2$ is

$$I(\tilde{f}_1, \tilde{f}_2) = 0 .$$

In order to establish a statistical linkage between the probability systems representing a communication channel it is necessary to be

$$I(\tilde{f}_1, \tilde{f}_2) \neq 0 .$$

Since it holds

$$H_{\text{tot}} = H^{(1)} + H^{(2)} - I(\tilde{f}_1, \tilde{f}_2) ,$$

where H_{tot} represents the entropy of joint probability distribution given on the set of ordered couples of elements from sets $S^{(1)}$ and $S^{(2)}$ and $H^{(1)}$ or $H^{(2)}$ is the entropy of individual probability system $\Sigma_f^{(1)}$ or $\Sigma_f^{(2)}$, respectively, the enlargement of statistical linkage between the random variable $\tilde{f}_1$ and $\tilde{f}_2$ effects upon the total physical entropy of systems $\Sigma_f^{(1)}$ and $\Sigma_f^{(2)}$. In consequence of it, by any creation of statistical linkage between the systems $\Sigma_f^{(1)}$ and $\Sigma_f^{(2)}$, its total physical entropy is descreased. Hence, any change of the statistical linkage of the systems $\Sigma_f^{(1)}$ and $\Sigma_f^{(2)}$ is necessarily accompanied by an entropic one as well.

However, the creating of entropic linkage between the physical systems is generally connected with the physical interaction between them. At various demands required (from $I(\tilde{f}_1, \tilde{f}_2)$ one may generally find the most suitable physical probability systems, where these are optimally realisable. For instance at the measurement such measuring instrument is to be chosen, which enables the creating of the maximal entropic linkage between the measured object and the measuring instrument. The same effort is also typical within the framework of the information theory, where a maximal statistical linkage between the source and the receiver of information is required. On the other hand while creating the entropic linkage between the two probability physical systems some physical interactions occur, which may change the structure of the individual probability systems.

Let us now turn to the exact determination of the properties of the physical probability system which represents the realization of a general probability system. We say that a physical probability system is a physical realisation of a general probability system $\{Y, \mathcal{J}. \tau, z\}$, if

1. there is a unique one-to-one way allocation of the elements from the space S (physical states) to the elements of the space, Y, i.e. $s_i = F(y_i)$; $s_i \in S$, $y_i \in Y$,

2. on σ-algebras $\mathfrak{S}$ and $\mathcal{J}$ the same probability measure is given while for the elements of subsets $S_j = [s_1^{(j)}, s_2^{(j)}, \ldots, s_n^{(j)}]$ and $E_j = [y_1^{(j)}, y_2^{(j)}, \ldots, y_n^{(j)}]$ of σ-algebras $\mathfrak{S}$ and $\mathcal{J}$, respectively, it holds $s_i^{(j)} = F(y_i^j)$,

3. for the values of the physical random variable $f(s_i)$ and random variable $z(y_i)$ the following equations are valid:

$$f(s_i) = z(y_i) , \quad i = 1, 2, \ldots, n .$$

Since there are many physical models of general probability systems, we have chosen a relatively simple one. This is a macrophysical model on which the relations between the physical and communication properties may be easily investigated.

2. THERMODYNAMICAL MODEL OF COMMUNICATION CHANNEL

We shall consider the channel, where a source and receiver of information are able to get a state from the set of physical states, which differ one from another only by different values of temperature of the bodies which represent physical systems that realize the source and receiver of information, i.e. the random variable determined on the set of physical states of systems allotted to the source and the receiver of information is the temperature. Statistical linkage is realized by providing such a physical environment between the source and the receiver of information which places them for a period of time into a thermal contact. As a result of such a contact heat transfer and a change of thermodynamic properties of the communication channel occur, mainly that of its thermodynamic entropy. It is obvious that such a physical realization of the communication channel is rare in practice but yields a model for a general investigation of mutual relations between the physical and information-theoretical properties of communication channels. It should be stated that the properties of the thermodynamical realization of a communication channel are similar also in all cases, where between the physical systems which represent realization of the source and the receiver of information a certain general transfer process takes place (for instance, the diffusion). In these cases it is only necessary to substitute the given state variable or amount of transfered physical quantity for the temperature or for the amount of heat, respectively.

The thermodynamical model of a communication channel is supposed to have the following properties:

The source of information is physically represented by a heat reservoir having different temperatures. We suppose that there are N thermal states of the heat reservoir assuming the temperatures

(2) $$T_i = x_i \,.\, \Delta T ,$$

where ΔT is a constant and x_i represents a function of thermal states. The values $T_1, T_2, \ldots, T_n$ are the values of random variable $\tilde{f}_1$.

The receiver of information represents physically a body with a small thermal capacity assuming, in consequence of thermal contact with the source reservoir, different temperatures, the values of which represent the values of the physical random variable $\tilde{f}_2$. Before each contact the receiver of information is in its starting temperature

(3) $$T_0 = l \,\Delta T ,$$

where l is a number. In order to get the change the receiver's temperature ΔT it is necessary to supply or take out from it an amount of heat Δq_0.

As a consequence of heat transfer in the physical system representing the communications channel, its physical thermodynamical entropy is changed, too.

The change of thermodynamic entropy Δs in case of a constant temperature on the receiver of information $T_0 = l\,.\,\Delta T(\Delta T \ll 1)$ is given by

$$\Delta s_i \doteq \Delta q_i \left|\frac{1}{T_0} - \frac{1}{T_i}\right|, \quad i = 1, 2, \ldots, N\,. \tag{4}$$

For the absolute amount of heat transferred during the thermal contact we have

$$\Delta q_i = c|T_i - T_0|\,, \tag{5}$$

where c represents the specific heat time mass of the receiver of information. Since the probability distribution of the thermal state is identical with that of the random variable $\tilde{f}_1$, we obtain for the mean values of thermodynamical entropy change as well as for the absolute value of transferred heat with respect to a thermal contact between the source and receiver of information

$$\overline{\Delta s} \doteq c \sum_{i=1}^{N} p_i \frac{(T_i - T_0)^2}{T_0 T_i} \quad \text{or} \quad |\overline{\Delta q}| = c \sum_{i=1}^{N} p_i |T_i - T_0|\,, \tag{6}$$

respectively. We suppose that the communication channel is noiseless, so that the elements of transfer matrix has only diagonal elements different from zero. The information contained in random variable $\tilde{f}_1$ about the random variable $\tilde{f}_2$ turn out to be

$$I = -\sum_i p_i \log p_i\,. \tag{7}$$

Using relations (6) and (7) we may find the sought relation between the physical and thermodynamical properties of considered communication channel. For the sake of simplicity, we shall determine these relations when assuming an uniform probability distribution of random variable $\tilde{f}_1$, i.e. $p_i = 1/N$, $(i = 1, 2, \ldots, N)$, and for integral $x_i = 1, 2, \ldots, N$ and l (see Eqs. (2) and (3)). For the mean charge of thermodynamical entropy $\overline{\Delta s}$ one obtains from Eq. (6)

$$\overline{\Delta s} \doteq (\Delta q_0/N) \sum_{i=l+1}^{N} (i-1)\left[(1/i\,\Delta T) - (1/i\,\Delta T)\right] + \sum_{l-1}^{i=1} (l-i)\left[1/i\,\Delta T) - \right.$$
$$\left. - (1/l\,\Delta T)\right]. \tag{8}$$

Eq. (8) represents expression, which may be rearranged into the form

$$\Delta s \doteq (\Delta q_0/N\,\Delta T)(R_1 - R_2 + R_3 - R_4)\,,$$

where R_1, R_2, R_3 and R_4 are certain sums. Taking into account that

$$\sum_{i=1}^{N} \frac{1}{i} \approx C + \ln N + \frac{1}{2N}, \quad N \gg 1;$$

where C is Euler constant ($C = 0{\cdot}5772\ldots$), these sums can be evaluated getting the values

$$R_1 = \sum_{i=l+1}^{N} (i - l)/l = -N + (l + 1) + \frac{(N + 1)N}{2l} - \frac{(l + 1)}{2},$$

$$R_2 = \sum_{i=l+1}^{N} (i - l)/i = N - (l + 1) - l\left[\ln (N/(l + 1)) + \frac{1}{2N} - \frac{1}{2(l + 1)}\right],$$

$$R_3 = \sum_{i=1}^{l-1} (l/i - 1) = -(l + 1) + l\left[\ln (l - 1) + C + \frac{1}{(l - 1)}\right],$$

$$R_4 = \sum_{i=1}^{l-1} (1 - i/l) = \tfrac{1}{2}(l - 1).$$

Substituting R_1. R_2, R_3 and R_4 into Eq. (8), we get

$$\overline{\Delta s} \doteq (\Delta q_0/N\,\Delta T) . \{2(l + 1) - 2N + [(N + 1)N/2l] + l . \ln N - l . \ln (l + 1) +$$
$$+ \frac{l}{2N} - \frac{l}{2(l + 1)} + \frac{l}{2(l - 1)} - \frac{3}{2}(l + 1) + l . \ln (l - 1) + lC - \tfrac{1}{2}(l - 1)\},$$

which for N, $l \gg 1$ turns out to be

$$\overline{\Delta s} \doteq (\Delta q_0/N\,\Delta T)\{N^2/2l - 2N + l(\ln N + C) + 1\}. \tag{9}$$

The expression (9) gives the average change of thermodynamic entropy to a signal at N thermal states of the source of information and at the starting temperature of the receiver $T_0 = l\,\Delta T$. The expression depends, however, on the starting temperature determined by l. It is therefore interesting to find such a value of l, for which the average change of thermodynamic entropy Δs gets its extreme value. In order to simplify the situation mathematically, let us assume that l can change continuously. For the extreme value of the expression for Δs in dependence on l the necessary condition is given by the equation

$$\mathrm{d}(\overline{\Delta s})/\mathrm{d}l = 0. \tag{10}$$

Equation (10) is satisfied, when

$$l_{\min} = N/[2(C + \ln N)]^{0,5}, \tag{11}$$

where the function $\overline{\Delta s}(l)$ gets its minimum value. Substituting Eq. (11) into Eq. (9), we obtain the minimum value for the average change of thermodynamic entropy of a system source-receiver of the information at the communication channel

$$\overline{\Delta s} \doteq (\Delta q_0/\Delta T) . \left\{\sqrt{[2(C + \ln N)]} - 2 + \frac{1}{N}\right\} . \tag{12}$$

An important physical parameter of the transfer process is the amount of heat, being transferred between the source and the receiver of the information during the communication process. For the average absolute value of the amount of heat transferred between the source and the receiver of the information we obtain the following expression

$$\overline{|\Delta q|} = \{ \sum_{i=l+1}^{N} (i - 1) + \sum_{i=1}^{l-1} (l - i)\} \frac{\Delta q_0}{N} = \tag{13}$$

$$= \left\{(N + 1) N/2 + (\tfrac{1}{2}[l(l + 1)] - lN + (\tfrac{1}{2}) [l(l - 1)] \frac{\Delta q_0}{N}\right\} .$$

When N, $l \gg 1$, Eq. (13) turns out to be

$$\overline{|\Delta q|} = \Delta q_0[N/2 + l(l/N - 1)] . \tag{14}$$

For $|\Delta q|$, as a function of l, we may find an extreme value, too. The value l, at which $|\Delta q|$ acquires its minimum value, satisfies the equation

$$l'_{\min} = N/2 .$$

Substituting $l_{\min}$ into Eq. (14), we have

$$\overline{|\Delta q_m|} = \frac{\Delta q_0}{2} . \frac{N}{2} . \tag{14a}$$

However, putting $l'_{\min}$ from Eq. (11) into Eq. (14), it results

$$\overline{|\Delta q|} = \Delta q_0\{(N/2) . (1 + 1/(C + \ln N) - \sqrt{2}/\sqrt{(C + \ln N)}]\} . \tag{15}$$

For the uniform probability distribution Eq. (7) turns out to be

$$I = \ln N .$$

Substituting for expression $\ln N$ the information I in expressions (12) and (15) we get the asymptotic relation $N \gg 1$ between the average change of entropy $\overline{\Delta s}$ and an absolute mean value of the transferred heat $\overline{|\Delta q|}$.

$$I \approx \ln \frac{\overline{|\Delta q|}}{2 \Delta q_0} , \tag{16}$$

$$I \approx \varkappa . (\Delta s)^2 , \tag{17}$$

where $\varkappa$ is a constant. The amount of transferred information is therefore uniquely functionally connected with physicall parameters of the communication channel. From all that been so far, it follows that it is impossible to transfer the information without a change of thermodynamic entropy as well as without a heat exchange in a system of the source-receiver by the thermodynamical communication channels. Besides, in a stationary thermodynamic state the total system of source-receiver of the information has the same temperature; in order to cause the information transfer it is necessary for the system to be in thermodynamically non-stationary state.

3. OPTIMIZATION OF THERMODYNAMICAL COMMUNICATION CHANNEL

The relation derived in the foregoing section represents only a special case of sought problem for the given assumptions about the probability distribution and the function values of the random variables $\tilde{f}_1$ and $\tilde{f}_2$. It may be easily shown that the relation between the physical quantities of thermodynamical communication channel and the transferred information is dependent on the choose of the function values of random variable $\tilde{f}_1$. In order to illustrate it, we consider two special cases:

(i) Let

$$x_i = l(1 + \log p_i)\,, \quad i = 1, 2, \ldots, N\,. \tag{18}$$

Substituting Eq. (18) into (6), we obtain

$$I = \frac{\overline{|\Delta q|}}{\Delta q_0}\,.$$

(ii) We take for the functional values $x_1, x_2, \ldots, x_N$ the solutions of the set of following equations

$$(x_i - l)^2 + x_i l \,.\, \log p_i = 0\,, \quad i = 1, 2, \ldots, N$$

the relation $I = f(\Delta s)$ adopts the form

$$I = \overline{\Delta s} \frac{\Delta T}{\Delta q_0}\,.$$

In consequence of it, the question arrises how to optimize the considered communication channel, i.e. how to choose the values T_i $(i = 1, 2, \ldots, N)$ or the probability distribution $p_1, p_2, \ldots, p_N$ of the random variable $\tilde{f}_1$, respectively, in order to obtain the extreme value for information or for the mean values of the change of thermodynamical entropy and amount of transferred heat when the mean change of thermodynamical entropy and amount of transferred heat or information, respectively, should be constant. This problem may be divided into two types:

(i) To find the function values of the random variable $\tilde{f}_1$ for a given probability distribution of it, so that the expression for mean change of thermodynamical entropy or mean amount of transferred heat, respectively, becomes extreme.

(ii) To find the probability distribution of random variable $\tilde{f}_1$ if its functional values $T_1, T_2, \ldots, T_N$ are given, so that the information gets its maximum value, i.e. to find the maximum value of information if the mean change of thermodynamical entropy or mean amount of transferred heat is given.

Both types of mathematical tasks lead to seeking of extreme value of certain expression when the boundary conditions are given. We turm now to the first type of task. It is to be found the extreme value of the expression

$$\overline{\Delta s} = c \sum_{i=1}^{N} p_i \frac{(T_i - T_0)}{T_i T_0} \quad \text{or} \quad |\overline{\Delta q}| = c p_i |T_i - T_0| \,,$$

respectively, when the value of information is given

$$I = -\sum p_i \log p_i \,.$$

This task leads to a trivial solution for extreme value of $\overline{\Delta s}$ or $|\overline{\Delta q}|$, respectively, namely

$$T_i = T_0 \,, \quad i = 1, 2, \ldots, N \,,$$

since for it become the expressions Δs and Δq zero, i.e. its minimum values. In order to obtain a non-trivial solution it must be added a suplementary condition regarding the functional values of random variable $\tilde{f}_1$. We shall take, for the sake of simplicity, the condition

$$\sum_{i=1}^{N} T_i = A \,. \tag{18}$$

Taking into account the condition (18) the extreme value for $\overline{\Delta s}$ or $|\overline{\Delta q}|$, respectively, must satisfy the equation

$$\frac{\partial \overline{\Delta s}}{\partial T_i} + \lambda_1 \frac{\partial}{\partial T_i} \left(\sum_{i=1}^{N} T_i\right) = 0 \quad \text{or} \quad \frac{\partial |\overline{\Delta q}|}{\partial T_i} + \lambda_1' \frac{\partial}{T_i} \left(\sum_{1=i}^{N} T_i\right) = 0 \,, \tag{19}$$

respectively, where λ_1 and λ_1' are the Lagrange's multiplicators. The solution of Eqs. (19) may be written in the form

$$T_i = \pm T_0 \sqrt{\left(\frac{p_i}{p_i + \lambda_1 T_0}\right)} \tag{20}$$

or

$$T_i = \frac{\lambda_1'}{p_i} \quad \text{for} \quad T_i > T_0 \,,$$

$$T_i = -\frac{\lambda_1'}{p_i} \quad \text{for} \quad T_i < T_0 \,,$$

 respectively. The multiplicators λ_1 and λ'_1 represent solutions of the equations

$$T_0 \sum_{i=1}^{N} \sqrt{\left(\frac{p_i}{p_i + \lambda_1 T_0}\right)} = A$$

and

$$\lambda'_1 \sum_{i=1}^{N} \operatorname{sgn} . \frac{1}{p_i} = A\,, \quad \operatorname{sgn} \begin{cases} + \text{ for } T_i < T_0 \\ - \text{ for } T_i > T_0 \,. \end{cases}$$

Similarly, the second type of task leads to searching of extreme value for the expression $I = -\sum_{i=1}^{N} p_i \log p_i$ by the following boundary conditions

(21) $$\sum_{i=1}^{N} p_i \frac{(T_i - T_0)^2}{T_i T_0} = D\,,$$

$$\sum_{i=1}^{N} p_i = 1\,,$$

or

(22) $$\sum_{i=1}^{N} p_i |T_i - T_0| = C\,,$$

$$\sum_{i=1}^{N} p_i = 1\,,$$

respectively. The necessary condition for getting the extreme value of expression (7) consists in satisfying the equations

(23) $$-\log p_i - 1 + \lambda_1 \frac{(T_1 - T_0)^2}{T_i T_0} + \lambda_2 = 0\,, \quad i = 1, 2, \ldots, N$$

or

$$-\log p_i - 1 + \lambda'_1 |T_i - T_0| + \lambda'_2 = 0\,, \quad i = 1, 2, \ldots, N\,, \text{ respectively,}$$

where λ_1, λ_2, λ'_1 and λ'_2 are the Lagrange's multiplicators. The solution of the Eqs. (23) has the form

(24) $$p_i = A \exp \left\{\lambda_1 \left(\frac{T_i}{T_0} - 2 - \frac{T_0}{T_i}\right)\right\} \quad \text{or} \quad p_i = A' \exp \{\lambda'_1 |T_i - T_0|\}$$

respectively, where

$$A = \exp \{1 - \lambda_2\} \quad \text{or} \quad A' = \exp \{1 - \lambda'_2\}\,,$$

respectively.

The multiplicators λ_1, λ_2, λ'_1 and λ'_2 may be determined, when inserting the solution (24) into the expressions (21) and (22), respectively. To determine the relation between the information and mean change of thermodynamical entropy we have to substitute the elements of probability distribution of functional values of random variable $\tilde{f}_1$ into the formulas (6) and (7). Generally, the extreme value of information, mean amount of transferred heat as well as the mean change of thermodynamical entropy of considered communication channel may be determined.

In the foregoing consideration we have been dealing with a physical realisation of a communication channel namely with a thermodynamical model of a transfer channel. As it has been previously stated the introduced model may be used mainly when a state variable represents the random variable of the physical probability system and when an amount of physical quantity must be transferred in order to change the state variable on the side of receiver of information.

It has been shown that the physical properties of communication channel effect immediately on its information-theoretical parameters. We have considered, however, only a macroscopical realization of a communication channel. When one takes into account that the current of heat represents in fact the current of energy the foregoing results emphasize that the transfer of information is necessarily connected with the transfer of energy [4]. Although in the macrophysical model it may be rather evident, in the microphysical region this fact means an important knowledge, since it determines a principle boundary for information transfer in the real communication channel [5].

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Fyzikálne a komunikačné vlastnosti termodynamického prenosového kanála

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V teórii komunikácie se prenosový kanál študuje často ako systém dvoch pravdepodobnostných objektov, medzi ktorými existuje určitá štatistická väzba. Fyzikálna realizácia takýchto matematických objektov má však bezprostredný vplyv na ich informačno-teoretické vlastnosti. Prenos informácie v reálnych fyzikálnych kanálov je spätý s určitým fyzikálnym procesom, ktorý podmieňuje tiež fyzikálnu situáciu vysielača a prijimača informácie. V tomto článku sa zaoberáme štúdiom vzťahov medzi fyzikálnymi a komunikačnými vlastosťami prenosového kanála, ak je prijímač a vysielač informácie realizovaný ako termodynamický systém pozostávajúci z dvoch telies, medzi ktorými prichádza k prenosu informácie prostredníctvom ich tepelného kontaktu. Ďalej je načrtnutý tiež postup pre optimalizáciu termodynamického modelu prenosového kanála z hľadiska množstva prenesenej informácie a veľkosti fyzikálnych zmien vzniklých u neho pri tomto prenose.

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