SOME ASPECTS OF CHOICE OF SWITCHING SCHEME FOR CONSTRUCTION OF OPTICAL SIGNALS' SWITCHING SYSTEM

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***Abstract**: Some aspects of choice of switching scheme for optical signals' square switching system's construction of big capacity are considered in the work. Variant based on scalar criteria of choice is offered and multicriteria optimization which allowed to receive results which can be applied at designing of optical signals' switching systems is made.*

***Keywords**: optical switching, optical signals' switching systems, switching schemes, scalar criteria of choice.*

***ACM classification keywords**: B.6 LOGIC DESIGN – B.6.3 Design Aids, B.4 INPUT/OUTPUT AND DATA COMMUNICATIONS - B.4.3 Interconnections (subsystems)*

Introduction

At present time it is impossible to imagine modern computer technologies, communications, management's and signals' processing's facilities without use of optical components. This is consequence of prompt development of fiber and integrated optical technologies on the one hand and with another – consequence of constantly growing requirements of channels' information capacity, information processing speed and telecommunication networks' (TN) reliability increase. Nevertheless till now switching schemes basically are realized on electronic elements that not only limits TN's operating speed as a whole but also demands additional engineering study of questions connected with optical and electronic elements' correct interaction's maintenance.

New problems which are directed on increase of information processing's speed demand revision of approaches not only to designing of telecommunication objects but also physical principles on the base of which these objects' components are constructed.

Graphic evidence of these problems' urgency is all-optical networks' (AON) concept based on application of exclusively optical technologies. Research of AON's concept has shown its application's efficiency first of all at transport level during creation of branched out network architecture. However at the same time creation of branched out optical networks demands decision of major problem – optical signals' switching systems (OSSS) realization. Analysis of problem's status in sphere of optical networks' creation [1-5] has shown that at present time fiber-optical transfer's systems' functioning's principles are studied well enough. At the same time questions of OSSS's realization are considered superficially and demand carrying out of further researches. Now there are only general conceptual approaches to OSSS's construction demanding development and careful analysis.

Statement of the problem

Existing optical signals' switching methods [6] provide necessity of preliminary transformation of optical radiation bearing the information in the electronic form (O/E), electric signal's switching and electrooptical reconversion (E/O) with the subsequent strengthening of optical radiation's power (fig. 1).

Such approach to optical signals' switching imposes restrictions on switching system's (SSt) bandwidth and its capacity. Realization of information signal's double transformation firstly essentially limits SSt's bandwidth (to 2,5 Gb/s) and secondly it is characterized by excessive power consumption that raises cost of device's operation.

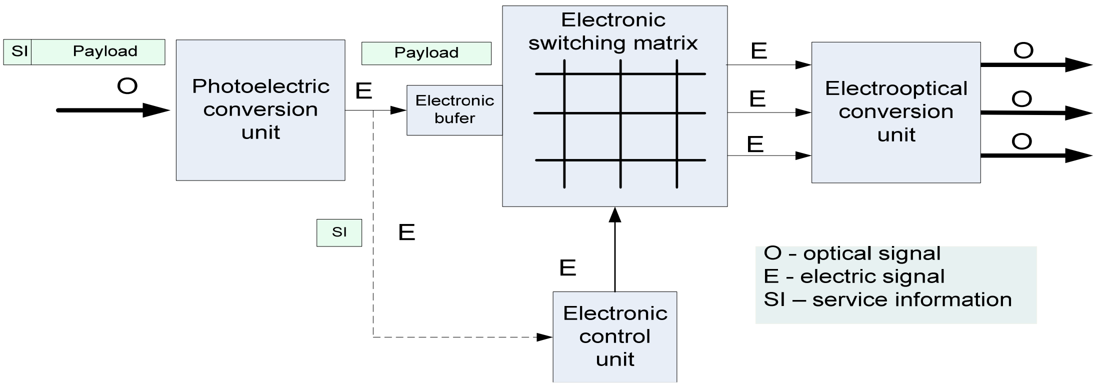

Figure 1 – O/E/O switching system's block diagram

Moreover raised power consumption and presence of cross-fire leads to restriction of similar switching systems' capacity which does not exceed 32x32. [7,8]

So electron-optical switching systems become TN's bottleneck and are deterrent at escalating of its bandwidth. To eliminate this phenomenon it is necessary to develop OSSS's model which will not only switch signals in the optical form but will also provide management of switching process by means of optical radiation. Here under the optical management of switching process it is understood management of information's carrying over between optical channels which is realized exclusively with use of optical technologies and allow to make transition to penta-bit speeds of information transfer in TN.

In all-optical switching system's model (fig. 2) information optical signal bearing some block of information and which is simultaneously being remembered by optical buffer (OB) arrives on entrance of optical management's module (OMM) which provides analysis of information block, allocates address information and generates optical signal of optical switching matrix's (OSM) management after its processing. Then optical signal is being taken from OB and following switching way arrives on exit of SSt. After increasing of power signal is being transferred by optical waveguide to the following switching node.

Despite advantages of all-optical approach to switches' construction its application meanwhile causes number of complexities. First of all it concerns OMM's realization using optical processors applied in war industry and nuclear power engineering cost of which exceeds cost of their electronic analogues in ten times [9].

One more obstacle in a way OSSS's development is complexity of optical buffer's with direct access (Optical RAM) working out. Fiber delay lines (FDL) existing for today are capable to accumulate optical signal only during limited time interval that is caused by extremely fast attenuation of optical radiation in tiny delay's loops [10].

In this connection actual problem is creation of hybrid OSSS's model for transition period which realizes "cut through" concept without buffering that will allow to raise efficiency of optical networks' functioning. Such OSSS's model should be deprived electron-optical transformation of information signal and switching management can be realized in electronic way. It will allow to solve problem of high power consumption and complexities of big capacity's switching systems' construction by use of microelectromechanical systems' (MEMS) technology [11] using high-efficiency's electronic processors accessible under the price for management of optical switching sphere.

Thus one of actual problems at OSSS's designing with capacity higher than 1024 ports is definition of the optimum switching scheme. This work is devoted to the decision of problem of choice of optimum switching scheme for square multicascade OSSS's development.

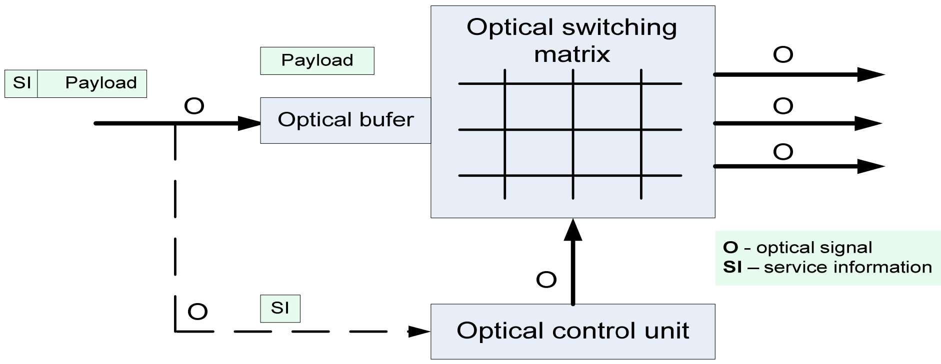

Figure 2 – O-O-O switching system’s block diagram

Basic principles of optical signals’ switching systems’ development

At the construction of spatial optical signals’ switching systems functional suitability and effectiveness of OSSS are being estimated using the following features [12,13]:

– blocking characteristics;

– number of basic elements;

– homogeneity of switching;

– crossing of waveguides.

Possibility of connection between any pair of free ports on the input and output (X_{in}, Y_{out}) is understood as blocking's characteristics of switching system. Depending on this characteristic there are non-blocking and blocking switching schemes [14].

Non-blocking of switching scheme is a key requirement for spatial optical signals' switching systems. Meanwhile non-blocking switching schemes in turn are divided into:

– non-blocking in the strict sense;

– non-blocking in the wide sense;

– non-blocking with rerouting.

Non-blocking switching schemes in the strict sense is a type of schemes that does not require rerouting of any connection when using any handshake.

Non-blocking switching schemes in the wide sense characterizing by the lack of appropriate rerouting of existing connections only in case of use of specific connection’s establishment’s procedure.

These first two types of non-blocking switching schemes today can be effectively used for the construction of OSSS. This is because the non-blocking schemes require tunable rerouting of existing connections which is problematic because of the need in optical signal’s buffering.

Under the basic element (BE) multistage switching scheme it is understood the switching device 2x2 or 1x2. Consequently at the stage of switching system’s design it is necessary to minimize the number of basic used elements which allows reducing of the developed device’s elements. Crossing of waveguides is necessary to minimize or eliminate altogether since it determines the appearance of optical power loss and transition loss as a result of the interaction of light beams.

Under the homogeneity of the switching it is meant equality of minimum and maximum number of primitives that will be an optical signal before it reaches the output switching system. Given the fact that each basic optical element introduces attenuation the design of OSSS should strive to ensure that firstly the number of basic elements through which the optical signal has been minimal and secondly, the minimum and maximum losses signals must be identical. Among the existing schemes of switching devices’ combining satisfying non-blocking it can be distinguished: matrix, scheme of Benesh, scheme of Shpanke and scheme of Shpanke-Benesh [12]. The main characteristics of non-blocking switching schemes are shown in table 1

Table 1 – Features of non-blocking switching schemes *NxN*

Scheme / Features	**Matrix**	**Benesh**	**Shpanke-Benesh**	**Shpanke**
Non-blocking	In the wide sense	With rerouting	With rerouting	In the strict sense
Number of BE	N^2	*N(2log2N-1)/2*	*N(N-1)/2*	*2N(N-1)*
Maximum losses	*2N-1*	*2log2N-1*	*N*	$2\log_2 N$
Minimum losses	*1*	*2log2N-1*	*N/2*	$2\log_2 N$
Homogeneity of switching	No	Yes	No	Yes
Crossing of waveguides	No	Yes	No	Yes

The solving of the task of switching scheme’s selection

There is a set of switching schemes Ω consisted of certain variants ω_i so that each certain variant $\omega_i \in \Omega$ is considered to be a point in a space of quality’s indexes and a set of possible variants Ω is defined as an existence domain: $\Omega = \{\omega_i\}$, $i = \overline{1, N}$.

Alternative variants of homogeneous set Ω are presented by minimum final descriptions corresponded to parametric of switching scheme $P = \{p_j\}$, $j = \overline{1, J}$ that describes adequately of each variant of homogeneous set Ω. The set of characteristics $\{p_j\}$ for switching schemes $\Omega = \{\omega_i\}$ consists of subset of quality’s indexes $\{k_l\}$ and subset of conditions $\{У_z\}$. The set of alternatives that satisfies combination of circumstances C_∂, that is acceptability requirement is an acceptable set Ω_∂.

Taking into consideration that a key condition of realization of OSSS is a requirement of non-blocking switching scheme the set Ω_∂ composes from the following switching schemes: matrix scheme W_1, scheme of Benesh W_2, scheme of Shpanke-Benesh W_3 and scheme Shpanke W_4.

The problem of choice is to choose a variant from a set of possible switching schemes $\Omega_д$ that has the best meaning k_l in terms of accepted criterion formulation.

Before creating criterion formulation $K=\{k_1,\ldots,k_M\}$, it's necessary to display switching schemes' characteristics on number scale. An ordinal scale is used to describe qualitative characteristics such as type of non-blocking and switching homogeneity. Quantitative characteristics such as number of basic elements, minimum and maximum loss are displayed on absolute scale.

Let k_1 is type of non-blocking switching scheme, k_2 – number of basis elements, k_3 – maximum loss, k_4 – minimum loss, k_5 – homogeneity of switching, k_6 – crossing of waveguides. So criterion formulation K has the following form:

$$K = \{k_1 \to \max, k_2 \to \min, k_3 \to \min, k_4 \to \min, k_5 \to \max, k_6 \to \max\} \quad (1)$$

In consideration of the fact that switching schemes' characteristics have different physical dimensions, it's necessary to do normalization of datum value. Meanwhile influence of every normalized index on efficient feature will be comparable, if a range of possible changes of each index is common. There to the following formula (3.5) is used:

$$k_1 = \frac{(k_l - k_l^*)}{(k_l^{**} - k_l^*)} \quad (2)$$

where $k_l^* = \min k_l \in \{k_l\}$, $k_l^{**} = \max k_l \in \{k_l\}$.

Applying the formula (2), characteristics of non-blocking of switching schemes after normalization is received for every characteristic k_l.

Determination of used selection criterion is an important step of task's solving. Vector criteria (Pareto and Slater criteria) permit to reject the worst variants and to reveal not bad but effective by Pareto and Slater. The main feature of vector criteria is objectivity because quality's indexes in such criteria are independent [15].

Taking into consideration the fact that formulated problem in this work provides for presence of independent quality's indexes (particularly homogeneity of switching depends on number of minimum and maximum loss), the use of vector criteria is unreasonable.

More over one of the main demand to use Pareto and Slater criteria is comparability of variants. Variants are comparable, if all quality indexes' meanings of a variant are more (or less) then the other variant. If it's not, the variants are incomparable. Preliminary analysis of initial set of permissible variants shows a small number of comparable variants that helps to make a conclusion about inefficiency of use of vector criteria for solving assigned problem.

Distinctive feature of scalar criteria is a possibility to receive the only variant of solution. However, a scalar criterion has a great part of subjectivity of a person who makes decision. In the case of solving a problem of choice of switching schemes, a function of a selection becomes a functional that is a complex quality index which reflects cumulative target effect. So it's reasonable to use an integral test of comparison of alternatives.

A ranking method is used for fixing peer reviews of weighting factor, because this method provides for the possibility of accurate estimation of importance of each index of selected variant. The essence of the method is estimation of quality indexes on relative scale (for example, over the range from 1 to 10). According to this method, weighting factor for M indexes are calculated with the help of the formula (3)

$$a_l = \lambda_l / \sum_{l=1}^{M} \lambda_l , \quad (3)$$

where λ_l – value index of *l* factor.

Meanwhile, the following formula (4) is used for M weighting factors.

$$\sum_{i=1}^{M} a_l = 1, \qquad a_l \geq 0, \qquad \overline{l = 1, M}, \quad (4)$$

Estimation of quality indexes on 10 point scale is seen in a table 2.

Table 2 - Estimation of quality indexes on scale of importance.

Quality indexes	**Mark**
Type of non-blocking, a_1	10
Number of basic elements, a_2	3,51
Minimum loss, a_3	1
Maximum loss, a_4	1,49
Homogeneity of switching, a_5	2
Crossing of waveguides, a_6	1,8

Weighting factor of every quality index is defined with the help of equation (3) that permitted to solve the task of selection of switching schemes by means of integral criterion of additive type (5).

$$W' = \sum_{l=1}^{M} a_l k_l, \qquad l = \overline{1, M} \quad (5)$$

Calculation results of integral criterion of selection for every switching scheme (SS) W_i are given in figure 3.

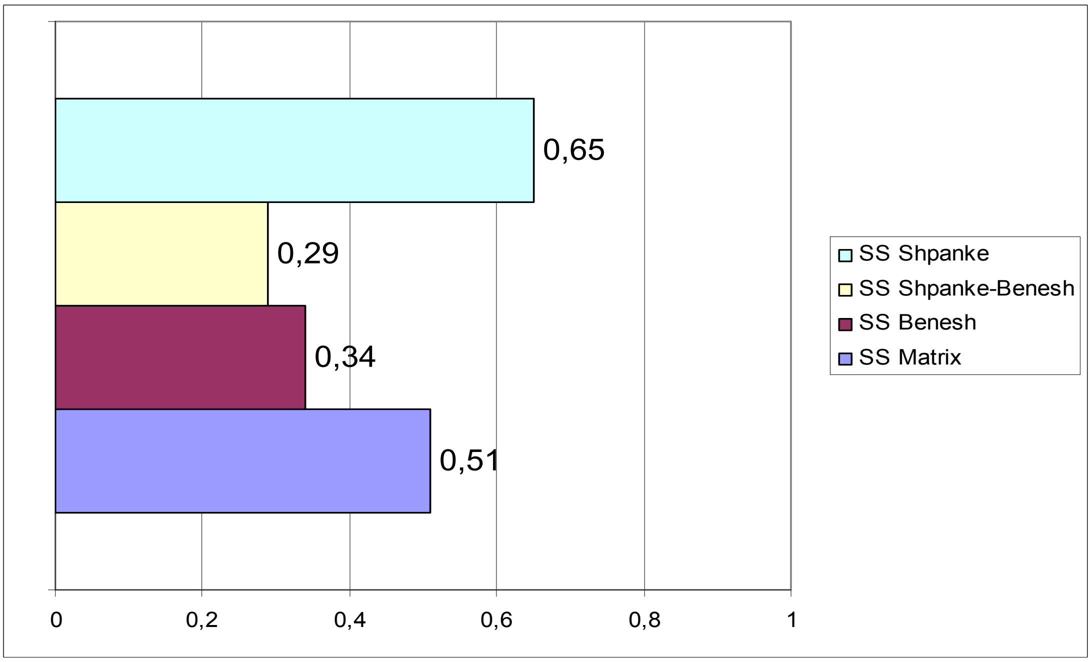

Figure 3 – Indexes of integral criterion of selection for non-blocking switching schemes.

Thereby calculation results shows that alternative W_4 (switching scheme of Shpanke) is optimal, because it’s an only scheme among all the schemes satisfies strict non-blocking condition.

Conclusion

Introduced in the work approach for the selection of optimum switching scheme for switching system’s development permits to confirm the explicitly that conducting of multiobjective optimization is characterized by the great subjectivism of a person who makes a decision. Adequacy of such optimization depends on person’s qualification and professionalism.

Problem’s solving with use of integral criterion permitted to define optimality of switching scheme Shpanke usage for construction of square high capacity’s optical signals’ switching systems. Indubitable advantage of Shpanke’s switching scheme is a characteristic of strict nonblocking. But great amount of 1x2 devices are needed for its realization. Another switching schemes considered at the problem’s solving can be used to construct multistage switching systems of optical signals only when problems of optical realization of existing connects’ rerouting is solved.

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The main areas of research: all-optical networks, switching of optical signals