THE BASE MODULE OF PICOSECOND AMPLIFIER WITH RISETIME INVARIANCE

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The new problem of stabilization of the pulse risetime depending amplitude in nonlinear amplifiers is considered. Modeling of the amplifier sections is carried out, and on the basis of differential transformation the condition of invariance of the response risetime to amplitude of the source signal is determined. It is established that nonlinear properties of transistor results to strong dependence of the risetime from effect amplitude. The numerical-analytical minimization way of the temporary parameters independence from pulse effect amplitudes have been offered.

1. Background

Recently the great successes in the high-voltage picosecond pulse generation, shaping, amplification and control of parameters are achieved. However the theoretical limits in achievement of the potentially characteristics are not achieve yet [1-2].

The main reason is difficulty of the microwave device synthesis with using of classical methods because of the classical models in the RLC basis and the operator functions has high order. Besides the sizes of active and passive elements become comparable with working band wave length [1]. The dependence of parameters of pulse signals (delay, form, amplitude) is followed from the geometrical sizes of elements and their connections. Therefore researches of the signal transformation processes and the high-speed problem complex decisions, based on the system theory are necessary required. In this connection the questions of search and development of the new concepts and approaches are urgent to research.

In the paper the characteristics of picosecond amplifiers developed in the Picosecond Technique Labs of Tomsk Polytechnic University are presented. The picosecond device research methodology is offered, which permits partially to solve one of the problems of the risetime response stability in the pulse amplifiers.

2. Condition of the risetime invariance

A main way of retain of the signal form in a wide amplitudes range is linearization of system [3]. Decision of this problem is suggest an invariance of the target form to the effect amplitude. Therefore linearization of pulse systems can be based on approximation of the form or separate parameters of the nonlinear system responses to the form of the response of some hypothetical linear system.

We shall determine the invariance condition [4] of the pulse risetime in the nonlinear system. The equation of the system we describe in a kind [1]:

$$\sum_{j=0}^{\infty} a_j(x)\frac{d^j x}{dt^j} = E1(t) \qquad (1)$$

where $x \in D(t)$ is response of system; $E \in U(t)$ is source signal amplitude; t is continuous time; n is system order; $a_j(x)$ are the nonlinear functions or coefficients for nonlinear system or coefficients for linear systems; D, U are some closed sets. We shall use of differential transformations [5]:

$$X(k) = \frac{H^k}{k!}\left[\frac{d^k x(t)}{d.t^k}\right]_{t=0} \leftrightarrow$$

$$x(t) = \sum_{k=0}^{\infty}\left(\frac{t}{H}\right)^k X(k) \qquad (2)$$

where $X(k)$ is discrets of a differential spectrum (image) of system variables $x(t)$; k is discretic argument; H is constant. With a glance to (2) and the property of differential transformation

$$\frac{d^l x(t)}{dt^l} = \frac{X(k+l)(k+l)!}{H^l k!}, l = 1,2,...$$

equation (1) is written as follows:

$$\sum_{j=0}^{n}\sum_{l=0}^{k} A_j[X(k-l)] * \frac{(l+j)!\,X(l+j)}{l!\,H^j} = \begin{cases} E, k = 0; \\ 0, k > 1, \end{cases} \qquad (3)$$

where A_j is image of a_j, and symbol * means an operation of discretic convolution

$$X(k)Y(k) = \sum_{l=0}^{k} X(k-l)Y(l).$$

If the system is linear, $A_j=a_j$ are constants, which in expression (3) are multiplied on the reciprocal image *X(k)*. The equation (3) represents itself the recurrence expression, from which the discrete of temporary function *X(k)* with the initial conditions are consistently determined:

$$X(k) = EH^k F_k(A_0, A_1, ..., A_n, E)/k!, \quad (4)$$

where F_k are some functions not dependent from *E*, provided that the system is linear. According to (4) we find:

$$x(t) = \sum_{k=0}^{\infty} Et^k F_k(A_0, A_1, ..., A_n, E)/k!.$$

The risetime t_z is determined on the *x(t)=0,5E* level:

$$0{,}5 = \sum_{k=0}^{\infty} t_z{}^k F_k(A_0, A_1, ..., A_n, E)/k!. \quad (5)$$

It is follows from this expression that risetime does not depends on effect if the system is linear. In the nonlinear system the functions *F* depends on the effect *E*, hence, in nonlinear systems defect of invariance is inevitable, that is deviation of characteristics of the nonlinear system from linear. So we receive a condition of invariance:

$$F_k[X(k), H, E] = k!X(k)/(EH^k) = \\ = f[X(k), H]. \quad (6)$$

For a simple example, we shall consider the elementary consecutive oscillatory LRC-circuit with the nonlinearity $C=C_0/x$, where *x* is a voltage on condenser. Differential equation of the circuit

$$\frac{d^2x(t)}{dt^2} + \frac{R}{L}\frac{dx(t)}{dt} + \frac{x(t)}{LC_0} = \frac{Ex(t)}{LC_0} \quad (7)$$

$$x(0) = dx(0)/dt = E$$

in the differential form can be written in the kind of [4]:

$$LC_0(k+1)(k+2)X(k+2)/H^2 + \\ + RC_0(k+1)X(k+1)/H + \\ + \sum_{l=0}^{k} X(k-l)X(l) = EX(k)$$

Substituting consistently *k=0,1,2...*, we find discrets *X(2), X(3),...* Taking into account that the solving is restored on discrets by equation (2), we note that only the first discrets is interested for us, as it take the most contribution to the total amount. For example, for *k=2* we have $X(4) = \frac{EH^3}{12LC_0}(\frac{RE}{2L} - E - \frac{R^3C_0}{2L^2})$, but for the linear system at $C=C_0$ same discrete will be $X_{lin}(4) = \frac{EH^3}{12LC}(\frac{R}{L} - \frac{R^3C}{2L^2})$, so condition $X_{lin}(4) = X(4)$ will be observed at the condition of $E = 2R/(R-2L)$, which will be condition of invariance, because of discrets *X(2)* for the linear and nonlinear circuit are identical, and *X(3)* has a small difference. In the real circuits *R>>L*, therefore the invariance condition of the solving of (7) to the amplitude *E* is simplified up to *E≥2*. Numerical account for the linear and nonlinear circuits easily shows that $x=x_{lin}$ for *E≥2*.

3. Practical results

The designed picosecond nonlinear pulse amplifier-shaper, the base section of which is shown on the fig. 1 has small dependence of risetime of pulse response from the effect amplitude (fig. 2). As a result of the circuit and packing optimization the influence of nonlinearity's to the characteristics is reduced [6]. The normalized characteristics of dependence of risetime from effect amplitude for investigation sections are shown on the fig. 3 (schedule 1 is not optimized, schedule 2 is optimized circuit). Maximum of this dependence is reduced in 3 times approximately. Risetime did not exceed 82 ps in the most effect amplitude, when influence of nonlinearity's is maximal value.

The developed module on the considered base section, which is shown on fig. 4, has following characteristics in a mode of linear amplification: gain - up to 14 dB, overcontrol of the transitive characteristic is 5%, maximum duration of pulse at recession of pulse on 5% is 100 ns, maximum output signal amplitude on 50 Ohm load is 2,5 V, maximum source and output VSWR does not exceed 1,5 in the 50 Ohm tract. In a mode of pulse formation the rise-time is 40 ps, overcontrol on front is 2%, recession of pulse by duration of 100 ns is 2%, maximum amplitude of target signal on 50 Ohm load is 2,5 V, amplitude of source pulse is 1 V, risetime of source pulse is not more than 1 ns.

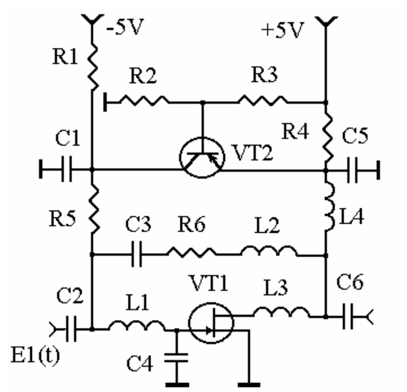

Fig. 1 – The base module of amplifier

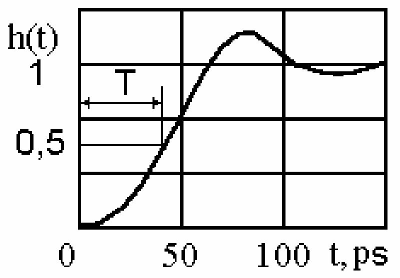

Fig. 2 – Example of the transient characteristics

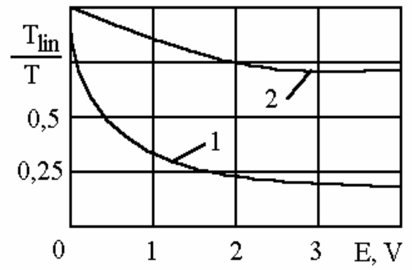

Fig. 3 – Risetime vs. amplitude

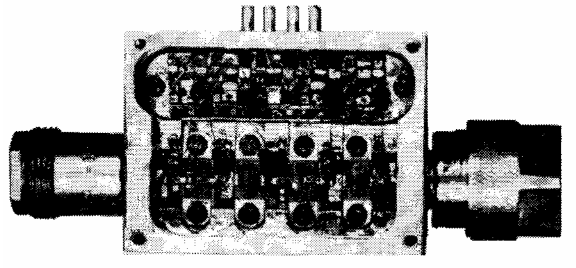

Fig. 4 – Photograph of amplifier

4. Conclusion

Picosecond and UHF devices of gain and control of signal amplitudes with pulse risetime up to 40 ps, working frequency bands from zero up to 10 GHz are used in systems of transfer, reception and information processing. On the base of received results of theoretical researches the amplifiers with 20 dB gain and frequency band from zero up to 11.3 GHz, rise-time from 40 ps up to 10 ns; dynamic range of 90 dB are developed. The devices are created on the FET's by the hybrid thin-film technology.

The new problem of invariance of the pulse risetime from effect amplitude in nonlinear amplifiers is considered. Basing of the differential transformations the condition of invariance is determined. Modeling of the amplifier sections is carried out. Distinctive features of amplifiers are simplicity of the circuit decisions, maximally simplified technology of packing and set-up, high repeatability and minimum cost, availability of the circuits of adaptation to varied work conditions. Such devices are applicable in subsurface radar, oscillography, in broadcast systems, including fiber-optic, experimental physics, etc.

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