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Tabulated Sections of Low-Frequency Dispersion Delay Lines on a Basis of Phase Circuits

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Abstract—There is noted essential importance of known methods of hardware analysis of low-frequency signals spectrum and drawbacks of dispersion delay lines (DDL) for dispersion analysis of such signals, and existent tables of pass-band DDLs do not allow to obtain transfer functions of DDL for low frequencies. There are shown possibilities of containing of tables for such DDLs sections on phase circuits of the first and the second orders. There is proposed new table of main parameters and zeros of Hurwitz polynomials for group delay times of DDL sections of low frequencies 5, 7, 9, 11, 13 and 15 orders, each of them is represented with separate Mathcad document.

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One of the most spread problems of measuring technique is a problem of development and realization of efficient methods of hardware analysis of frequency spectrum of electric signals [1, 2]. Efficiency of such methods depends mostly on structure and specificities of separate parts, appearing at measurement device. Simplicity and accuracy of these measurements, and also reliability of such device operation, evidently, must be related to initial signal specificities, i.e. measuring device must be adequate to this signal. For low-frequency signal, main spectral frequency band lies near coordinates origin and it can contain zero frequency, separate analyzer parts must be low-frequency.

There are known great amount examples of enough useful application of hardware analysis of just low-frequency signals in case of testing of different machines and mechanisms [3] for different biological, medical, geologic and the other research of natural phenomena [4].

Main parts in development of measurement systems are different spectrum analyzers, whose main part is dispersion delay line (DDL). Specificity of dispersion analyzers is specified by fact that their results are in more universal temporal space, not in frequency one. There are known other practically more essential advantages of dispersion- time analyzers of frequency spectrum [5].

But DDL of known dispersion analyzers, which are applied for spectrum analysis of just band signals with finite duration, have insufficient frequency band, whose necessary expansion do not allow to realize the DDLs with phase circuits. For low frequency signals low frequency DDLs with decreased amount of phase circuits may be adequate.

For realization of arbitrary DDL on phase circuits it is necessary to obtain transfer function of each circuit. As it is known [6], coefficients of DDL transfer functions depend on selection of correspondent Hurwitz polynomials. At that, dependently on selected criterion of proximity of function of group delay time (GDT) of DDL sections to linear function of GDT or function of phase-frequency response to parabolic frequency function, we can obtain different types of transfer functions in form of tables of main parameters and zeros of Hurwitz polynomials.

But known tables represent sections just band DDL for GDT function [6, Table. 3.11] and for PFR function [6, Table 3.12] on normalizing interval from lower boundary frequency $\omega_{\rm lw} = 1$ to upper boundary frequency $\omega_{\rm up} = 2$. For lower-frequency singles this tables are impossible to be applied.

For construction of low frequency dispersion spectrum analyzers it is necessary to obtain new table for GDT of DDL sections on normalizing interval from lower boundary frequency $\omega_{\rm lw} = 0$ to upper boundary frequency $\omega_{\rm up} = 10$ with graphic analytical method, which can be realized only in two stages: extremums localization and their adjustment to GDT linear function approximation with MathCad.

At that it is possible to realize DDL sections, containing only phase circuits of the second order or phase circuits of the first and the second order. But, since operation part of GDT function of phase circuits of the first order is monotonous function, then at the DDL output we can define uniquely distributed efficient

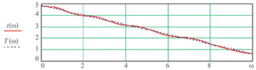

Fig. 1.

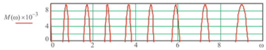

Fig. 2.

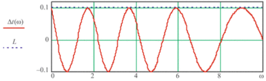

Fig. 3.

spectrum just in definite part of time axis. It means that phase circuits of the second order are applied only for correction of GDT function of phase circuits of the first order to obtain linear operating part of corresponding DDL section. Hence, we can state that it is necessary to use only the second variant of mentioned ones for DDL realization.

Principle of making of required table is shown on example of consideration of DDL section of the ninth order, which contains single phase circuit of the first order and four phase circuits of the second order.

Represented MathCAD document contains following notifications: m is scaling factor of GDT function, σ is column vector of real component of complex roots of Hurwitz polynomials for phase circuits of the second order, σ_0 is a root of Hurwitz polynomial of the circuit of the first order, Ω is imaging component Hurwitz polynomial roots for phase circuits of the second order, $T(\omega)$ is linear approximated GDT function, $t(\omega)$ is GDT function, approximating function of $T(\omega)$, t_{lw} is a value of linear GDT function $T(\omega)$, corresponding to frequency ω_{lw}, i.e. initial ordinate of this function, t_{up} is a value of linear GDT function $T(\omega)$, corresponding to frequency ω_{up}, i.e. finite ordinate of this function, $t_{\text{lw}} - t_{\text{up}}$ is a step of GDT function $T(\omega)$, defining a level of analized spectrum, obtained at the DDL output, $\Delta t(\omega)$ is a deviation of function $t(\omega)$ from linear function $T(\omega)$, $M(\omega)$ is absolute value (maximums) of this deviation, ΔM is a value of deviation absolute value, which selects only summits of these maximums, i.e. increases effect of their inequality, L is minimal value of leveled maximums of this deviation, D is DDL variance factor.

In Fig. 1 (MathCAD document) approximating and approximated GDT functions are represented, in Fig. 2 there are selected deviation maximums of approximating function deviation from linear GDT, and in Fig. 3 obtained Chebyshev's alternans are shown.

For localization of functions $t(\omega)$ extremums it is enough to modify summarizing limits of its analytical expression with definite order. At that planes in Fig. 1 there are the graphs of correspondent GDT functions and their maximums and minimums. For example, if lower and upper limits are set identical, then in Fig. 1 we obtain the graph of GDT function of the single phase circuit, if these limits difference is one, then we