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Signal Volume and Requirements to Analog-to-Digit Conversion

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Abstract—We specify conception of a volume of deterministic and random signals and define general requirements to analog-to-digit conversion.

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One of the main signal (signal system) parameters, defining, in particularly, its possibility of information transmission, is signal volume [1–4]. For deterministic signal $u(t)$, whose spectrum is $U(\mathrm{j}\omega)$, its volume V_s is defined [1] as

$$V_\mathrm{s} = F_\mathrm{s} T_\mathrm{s} D_\mathrm{s} = B_\mathrm{t} D_\mathrm{s}, \tag{1}$$

where F_s is signal spectrum width, T_s is signal duration, $D_\mathrm{s} = 10\lg(P_{\mathrm{s\,max}} / P_{\mathrm{s\,min}})$ is dynamic range, $P_{\mathrm{s\,max}}, P_{\mathrm{s\,min}}$ are maximal and minimal signal powers, correspondingly, $B_\mathrm{t} = F_\mathrm{s} T_\mathrm{s}$ is time basis of the signal.

Defining duration and spectrum width, we can use different criteria [2]. Mathematically grounded and consistent definition of some function can be obtained from its moments as a plane figure.

In this case spectrum width is defined as efficient width of a function $U(\mathrm{j}\omega)$:

$$F_\mathrm{s} = \frac{1}{2\pi}\sqrt{\frac{1}{E_\mathrm{s}}\int_{-\infty}^{\infty}(\omega-\omega_0)^2 |U(\mathrm{j}\omega)|^2 \mathrm{d}\omega},$$

where $\omega_0 = \sqrt{\frac{1}{E_\mathrm{s}}\int_{-\infty}^{\infty}\omega |U(\mathrm{j}\omega)|^2 \mathrm{d}\omega}$ is mean value of spectrum frequency, $E_\mathrm{s} = \int_{-\infty}^{\infty} u^2(t)\mathrm{d}t = \frac{1}{2\pi}\int_{-\infty}^{\infty} |U(\mathrm{j}\omega)|^2 \mathrm{d}\omega$ is signal energy, and duration T_s is efficient width of function $u(t)$:

$$T_\mathrm{s} = \sqrt{\frac{1}{E_\mathrm{s}}\int_{-\infty}^{\infty}(t - t_{\mathrm{mean}})^2 u^2(t)\mathrm{d}t},$$

where $t_{\mathrm{mean}} = \sqrt{\frac{1}{E_\mathrm{s}}\int_{-\infty}^{\infty} t u^2(t)\mathrm{d}t}$ is mean point of a signal.

In case of periodical signal $[u(t) = u(t + kT_{\mathrm{per}}),\ k \in \{0, \pm 1, \pm 2, \ldots\}]$ $T_\mathrm{s} = T_{\mathrm{per}}$. In case of signal with finite spectrum $[U(\mathrm{j}\omega) = 0$ if $\omega > 2\pi F_{\max}]$ $F_\mathrm{s} = F_{\max}$. Definition of dynamic range of deterministic signals is realized using maximal and minimal powers $P_{\mathrm{s\,max}}$ and $P_{\mathrm{s\,min}}$, which, in contrast to definition F_s and T_s, allow of another explanation, exceeds the bounds of parameters of signals themselves and including system parameters (noises level, level of nonlinear distortion, elements electric strength, etc). Physically, $P_{\mathrm{s\,max}}$ characterizes some maximum of possible signals values area, $P_{\mathrm{s\,min}}$ is minimal element of this area.