Suppression of the External Interferences and Spectral Distortion by means of Simultaneous Separation of Signal and Interferences

Part 2. Suppression of a Single Interference and a Complex of Interferences

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Impulse and narrow-band sinusoidal interferences play a great role among external interferences that take action on communications systems. Their action may cause quality degradation of communication or even its collapse. Many present day methods based on rejection of spectrum fields containing narrow-band interferences or on processing tract blanking during the moments of pulse interference may be ineffective. The cause of that is growing of nonlinear and intersymbol distortions. Damage from them may be commensurable with damage from external interference.

Here is described the method of "partial frequency diversity" that is used for suppression of narrow-band and pulse interferences.

The preconditions for described method are the communication systems using frequency diversity. The base of the method is:

1. Narrow-band interference After the superposition with frequency-diversed informational signals the narrow-band interferences in every diversed signal are situated in different places of the spectrum of the informational signal. Relatively to this, spectrum interferences are found to be frequency-diversed too. In that case interferences will be rejected from a useful signal. Useful signal will be kept without any destortions on the fields of rejection
2. Pulse interference. Signals, transmitted in diversed channels, have to be moved each relatively others on time interval, longer than noise action. In a receiver signals will be shifted on time. In that case pulse interferences will become diversed on time axis They may be eliminated before combining of signals in the moments of pulse action

Essence of the method may be described by a sequence of operations (fig. 1). A signal with partial frequency diversity is generated in a transmitter In order to realize that information signal $x(t)$ must be summed with signal $y(t)$. The signal $y(t)$ is $x(t)$ shifted on time Δt and frequency Δf. (Δt and Δf are not interdependent). Signals $y(t)$ and $x(t)$ also are not correlated with each other in the same moments of time. Summed signal $z(t) = y(t) + x(t)$ is radiated by a transmitter.

Receiving side gets a sum of useful signal $z(t)$ and some narrow-band external interference $\xi(t)$ with

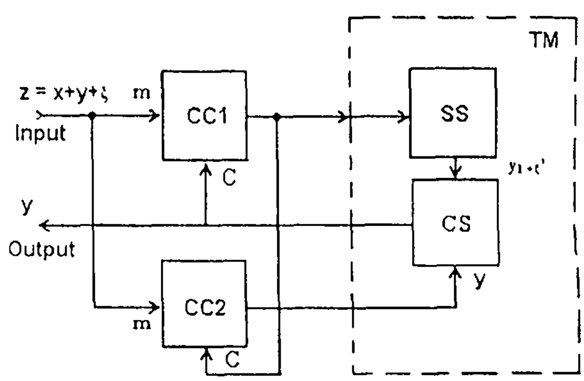

fig. 1

Part 1 of this article has appeared in ISC April 2004 a central frequency f_n. The signal *z(t)* is divided to *x(t)* and *y(t)* by two correlational compensators CC1 and CC2, that are engineered using one of standard schemes. Output of CC1 is connected to correlational input of CC2 and to Transformation Module (TM). In TM signal passes through the block of combining of signals (CS). Output of CC2 is connected to another input of CS. Output signal of CS is used as an output signal of the whole devise. From that output signal the correlational signal of CC1 is formed.

Signal *y(t)* is directed from the output of a device to the demodulator of the receiver. Parts of signals, coming to main input *m* that are correlated with a signal on correlational input *c* are eliminated by CCs.

Shifting scheme SS produces shifts on time and frequency axes. That shifts (Δf and Δt) are the same to shifts carried in informational signals in transmitter. Signals and interference on the output of CC are $y_1(t)$ and $\xi_1(t)$. $\xi_1(t)$ is the signal $\xi(t)$ shifted by Δf and Δt, $y_1(t)$ may differ from *y(t)* by phase.

Two signals with different attributes of interference components come to the input of CS. Here we see a situation that is distinctively equivalent to double frequency diversity. Interferences are shifted from each other on time and frequency and may be eliminated using various methods. Scheme of CS that realizes such function is shown on fig. 2. Switches Sw1 & Sw2 are used when pulse interferences take place. Rejection filters RF1 & RF2 – when narrow-band interferences take place.

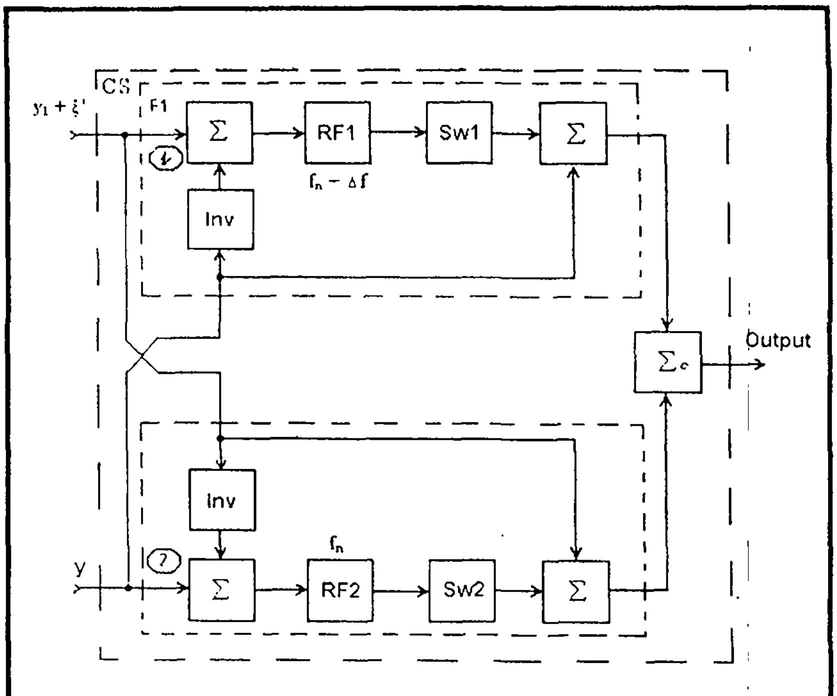

fig. 2

Action of narrow-band interferences.

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1 n $\xi(t)$ and $y_1(t)$ is adjusted before their combining. Sw1 & Sw2 here are opened constantly. Interferences $\xi(t)$ and $\xi_1(t)$ doesn't coincide by frequency. If the bandwidth of its spectrum is smaller than Δf then interferences may be rejected from the useful signal without great distortions. Reject bands of RF_1 & RF_2 are wider that the width of interference spectrum but they doesn't overlap each other (conversion gain of RF1 & RF2 is about 0 in a reject band and about 1 outside of it). Central frequency of RF1 is $f_n + \Delta f$, RF2 is f_n.

Voltage of interference doesn't exist on the output of adder Σ_0 (fig. 2). Voltage $\xi_1(t)$ shall be rejected after signals $y_1(t) + \xi_1(t)$ and *y(t)* pass through adder Σ, invertor Inv, anf filter RF1. That causes cutting out a part of a $y_1(t)$ spectrum in a reject band of RF1 on the frequency $f_n + \Delta f$. That part is replaced by the same part from *y(t)*, because *y(t)* and

$y_1(t)$ have the same phase and amplitude. In the signal $y(t)$, interference $\xi_1(t)$ is situated on the frequency f_n. That's why $y(t)$ doesn't contain interference on the frequency $f_n + \Delta f$. Since both signals pass through the same filter RF1, identity of removed and inserted parts of their spectrum is fulfilled automatically.

Also we may say the same about rejection $\xi_1(t)$ in RF2 and replacing removed part of signal y by associated part of signal $y_1(t)$. In the end, $y_1(t)$ and $y(t)$ are summed in Σ_0 and don't contain any interferences.

It's necesary to notice that $\xi_1(t)$ is taking place in the point 2 only during the process of transitional work. During transitional work the function $\xi_1(t)$ doesn't exist.

The depth of interference reduction depends on rejection quality of the filters. Distortions of a useful signal may be caused by insufficient equalizing of levels of signals of y and y_1 in points 2 and 1 and by insufficient sinchronity after phase tuning. That is determined by concrete realizations of the scheme.

Magnitude of Δf is limited on the one hand by the width of the spectrum of the narrow-band interference and on the other hand by the intention to make more narrow the common bandwidth of signal spectrum $x(t) + y(t)$.

Several independent narrow-band interferences also may be eliminated by using the described method. For that needs several rejection filters have to be used. Necessary conditions for such case are:

- Δf must be larger than bandwidth of interference with the widest spectrum;
- neighbor interference bands mustn't overlap each other after shift by Δf;

Pulse interference. In that case spectrum rejection doesn't take a place. $\xi_1(t)$ and $\xi(t)$ are shifted on time. Switches Sw1 & Sw2 are closed for time of interference pulse. On their inputs during that time y_1 is used instead of y, then y instead of y_1 without jumps of amplitude and phase.

The modeling of the work of the scheme was produced on a PC. Transient process of the establishment of stationary work was simulated. During modeling some approximations were made. Informational signal of a communication system have been taken as a stochastic signal with a band Π_c with uniform spectrum inside it. Rejection filters have been taken as ideal, i.e. with Π-like characteristics with null conversion gain in rejection band. In the rejection filter a narrowband interference is rejected to the level of thermal noises of the receiver. The width of rejection band had to be larger than the spectrum bandwidth of an interference, but smaller than Δf (Δf must be chosen in each case according to that criteria).

Modeling algorithm is based on a consecutive changing of the input signal spectrum from the very beginning of device work. Let spectrum of an initial useful signal $x(t)$ be $G_x(t) = G_0$.

Spectrum of the signal $V(t)$ (output signal) in any moment of time may be shown as a sum of G_j with various summing coefficients a_j, i.e. $G_V = \sum_{j=0}^{N} a_j G_j$ (Here G_j is the spectrum of the signal $x(t)$ that is shifted on $j\Delta f$ at frequency axis and on $j\Delta t$ at time axis).

With the help of PC cycling changes of various components of output signals were examined. These changes model the transient process of converting $V(t)$ to $y(t)$.

The components G_{N+1}, G_{N+2}, are lying outside the band Π_c of tract and may be eliminated from it. That option is provided by $N = \Pi_c / \Delta f$. In other words, G_j spectrum moves outside the field of tract until disappearing when j grows.

Modeling has shown that in the first moments of time, on the output of the scheme, exist parts of the signal $y(t)$, $x(t)$, parts alike some times shifted $x(t)$, and so on. Number of these parts groves up, their total lever falls down, until only useful signal $y(t)$ will exist. Results of modeling are shown in fig. 3 and fig. 4. On Fig. 3 one can see level changes in time of first ten components of shifted $x(t)$

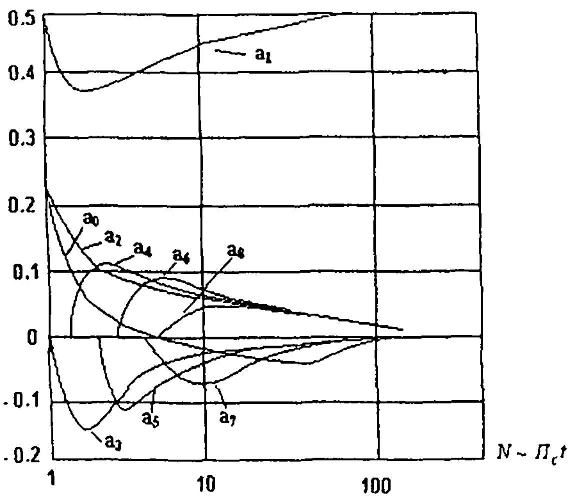

fig. 3

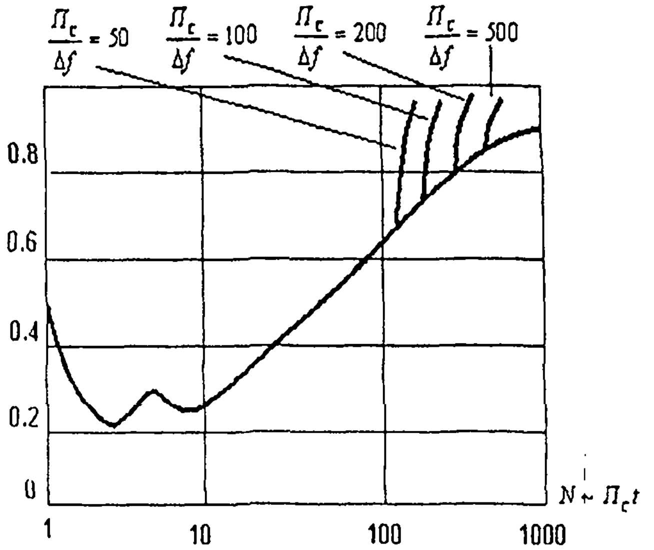

fig. 4

relatively to the whole level of the output signal for $\Delta f = 0.1\Pi_c$. The counting of the time is discrete and is proportional to $1/\Pi_c$.

Diagram on fig. 4 shows changing of the ratio of the power of process $y(t)$ to total power of output signal. In the beginning the transient process is oscillating, and after some moment we can see accelerated falling down of level of unuseful components. Coming of that moment can be determined by the ratio of Δf and Π_c and is conditioned by the gradual disappointment of other parts as far as their common frequency shift outside the Π_c band.

After that moment the informational signal is pured from external interferences.

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