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

Part 3. Suppression of a selective frequency distortion of spectrum of signals.

P A Polushin [†]

As a result of propagation of radio signals through scatter channels they are exposed to deformation which name fades. Generally the statistical structure of accidental process of fades of signals is rather complicated and in various sections of the frequency axis can differ. If the frequency band of a signal is less than interval of the frequency correlation of the channel ($\Pi_c < R_f$) all its frquency components fade synchronously, forming "smooth" fades. If a signal broadband $\Pi_c < R_f$, then there are the selective – frequency fades (SFF), in the channel.

Influence of SFF on a signal is equivalent to the passage of a signal through a certain linear filter with a non-uniform frequency response characteristic $K(\omega)$, the shape of which varies in time. For struggle against it the adaptive filters having equivalent characteristic close to $\frac{1}{K(\omega)}$ and aligning a spectrum of a signal before demodulation are used.

However in this case probably may be the following phenomenon. Let in some frequency band the signal level has fallen as the result of SFF below threshold. The adaptive filter (AF) will try to align the spectrum and will considerably lift amplification on this section of a spectrum. The level of additive thermal noises of this section of a spectrum will rise up to a signal level of other sections of a spectrum. That can result in deterioration of communication down to its break-up.

Further we shall describe the method avoiding these consequences. Its essence is the following. Let signaled a message represents some accidental process $X'(t)$ of which on a sending end of a communication line process $S_T(t) = X'(t) + Y'(t)$ is formed. Here $Y'(t)$ is produced by shift of all band of a spectrum process $X(t)$ on the frequency axis on some value Δf. (In some cases may be by shift also on time for interval Δt). *On a receiving end of a communication line signal* $S_r(t) = X(t) + Y(t)$, undergone to influence SFF is received. Both copies $X(t)$ and $Y(t)$ are separately taken from it. Then copy $Y(t)$ is shifted on the frequency axis on value Δf, forming signal $X_1(t)$, same as $X(t)$.

SFF influences on $S_r(t)$ and spectra of both signals $X(t)$ and $Y(t)$ are damaged But after the backward translation on frequency on Δf signals $X(t)$ and $X_1(t)$ have different damaged sections of a spectrum. At provision of an inequality $\Delta f > R_f$ identical sections of a spectrum of signals $X(t)$ and $X_1(t)$ are damaged by SFF independently and not simultaneously As the result when any section of a spectrum of one of these signals is damaged by fades, the corresponding section of a spectrum of

[†] Komissarova 17-1 Vladimir 600027, Russia

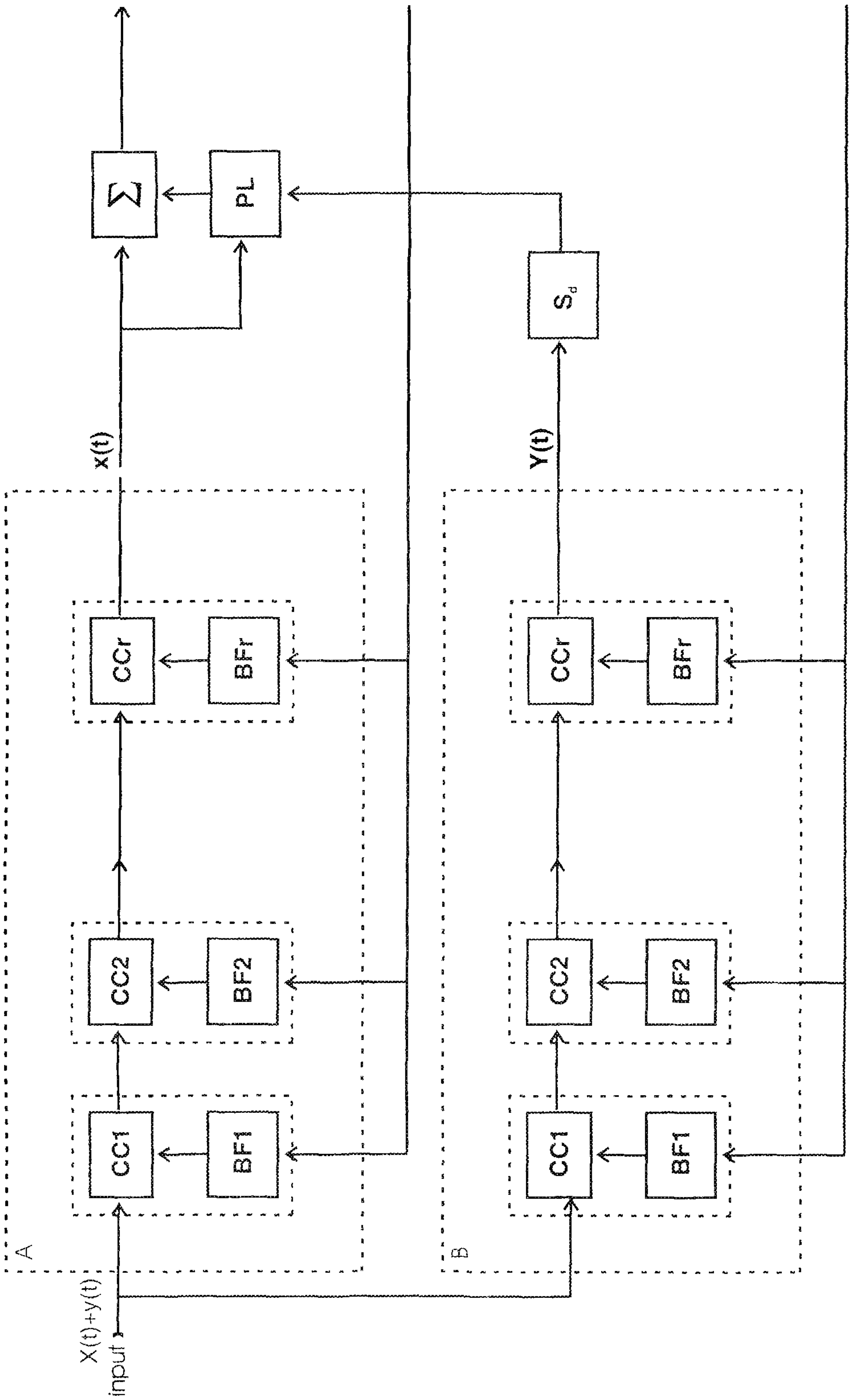

Fig. 1

other signal appears intact and the signal transmitted on a communication system is possible for restoring.

Break-up of communication is possible only when SFF have simultaneously happened on two different sections of the frequency axis. Such event is less probable, therefore application of the method as a whole increases stability of a communication system to SFF.

The method of forming of transmitted signal $S_T(t)$ is enough represented in the part I and the part 2 of this article. Therefore we shall consider a method of processing of signal $S_R(t)$ on a receiving end with the purpose of reception of copies $X(t)$ and $X_l(t)$. It is illustrated on fig. 1.

a) Stationary work, SFF is absent. There are two similar channels - A and B, each of them consists of r serially parts. The number of part r is determined by quantity of intervals of frequency correlation R_f of SFF, kept within the band of a spectrum of signal II_c. Every part contains correlational compensators CCj and bandpass filters BFj. Bandpass filters have the bands equal to Ri, and every band of a filter borders upon the bands of two neighbor filters. So all filters overlap a whole band of signal IIc. Filters of the channel A overlap a band of signal $Y(t)$, and filters of the channel B overlap the band of a signal $X(t)$.

Let's consider work of one channel. On inputs of all BF_j of the channel A moves the same signal $Y(t)$. Each of filters picks up from it the part of a spectrum and directs it to correlational input of the corresponding compensator. The certain part of signal $Y(t)$ is deleted from a signal passing through the separate compensator containing the sum $X(t) + Y(t)$. After transition of all compensators on the output of the last of there is only signal $X(t)$.

Similar process occurs in channel B, but here after passing of all compensators there

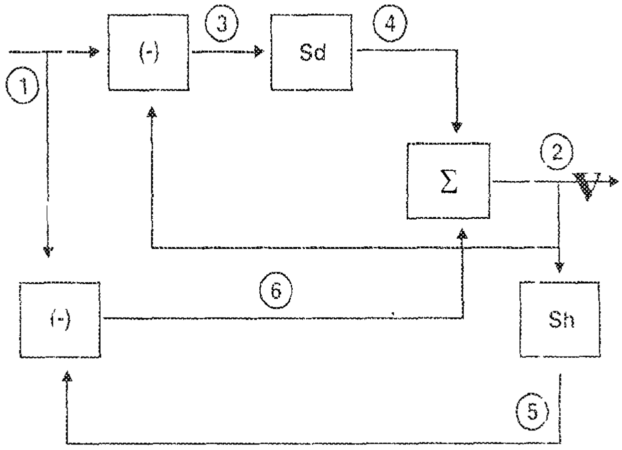

Fig. 2

is signal $Y(t)$. Further this signal $Y(t)$ transits through the circuit of shifting of a spectrum downwards (S_d) on value Δf. On its output the signal $X(t)$ is formed. After that in the adder Σ it is summed with the same signal $X(t)$, who has come from the channel A. Before addition phases and levels of added signals are equalized (in the block PL).

The spectrum of signal from an output of the adder is leveled in the adaptive filter AF and the received signal moves on the further processing in demodulator. This signal moves also on bandpass filters of the channel B and, after translation of a spectrum upwards on frequency Δf (in the block S_n) on bandpass filters of the channel A.

Signals $X(t)$ and $Y(t)$ are partitioned and so it turns out that by SFF are damage different sections of their spectrum. Therefore after their combining in a signal X_Σ any part of a spectrum does not fall on a level below a threshold and influence of SFF is removed (or weakened). After alignment in AF there is no dangerous increase of a noise level in any part of an output signal.

Let us consider any of compensators As on its correlational input is the signal only of one of the frequency bands, so this compensator does not influence on other bands of a spectrum of a signal By such consideration the circuit on each of frequency channels can be simplified (the bandpass filters in the channel can be excluded, all correlational compensators can be replaced with the blocks of subtraction), as shown in fig 2

We shall designate operation of translation of a spectrum of a signal upwards on the Δf frequency axis through H_u and operation of translation downwards on the frequency axis through H_d Then on input of the circuit (the point 1) we have a signal $U1=x+H_u x$, x original signal

Let on output of the circuit (the point 2) is output signal $U2=V$ Our task is to find a kind of this signal in a stationary work

On the output of the compensators of the channel A (the point 3) signal is $U3=U1-V$ After the circuit of shifting downwards on the frequency axis (in the block S_d) in the point 4 signal $U4=H_d U3$ In the point 5 after the shift of a signal upwards on the frequency axis (in block S_h) will be the signal $U5=H+V$ On the output of the correlational compensators of the channel B (the point 6) will be electrical voltage $U6=U1-U5$

Signals $U4$ and $U6$ are summed in the adder (let with factors 0.5) and form electrical voltage

$$U2=0.5(U5+U6)=V$$

If we shall substitute to this formula the expression for $U1$ $U6$ received before we shall get

$$V=0.5[H_d(x+H_u x-V)+x+H_u x-H_u V)] = 0.5\,[H_d x+x-H_d V+x+H_u x\ H_u V]$$

$$= x + 0.5\,(H_u+H_d)x\ 0.5(H_u + H_d)V$$

After regrouping we have

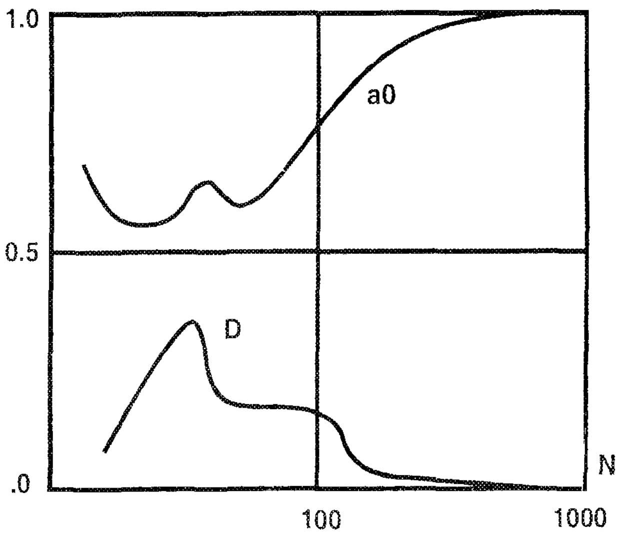

Fig 3

$$V+0.5(H_u+H_d)\ V=x+0.5\,(H_u + H_d)$$

$$[1+0.5\,(H_u + H_d)]\ V = [1+0.5\,(H_u + H_d)]x$$

So V = x and on the output of the arrangement is a signal identical to the original signal x

The behavior of set of these factors was modeled on a computer It was taken into account, that the automatic gain control in output signal $U2$ will support a constant average power $\overline{U}^2 = 1$ That was provided by normalizing of sets of factors αp, again received after each iteration

In actual conditions after each cycle unuseful spectrum components are shifting to both edges of the bandwith Hc and sooner or later will leave from the band and will disappear from total sum

One of the results of simulation analysis is submitted on fig 3 Here are the schedule of variation of a normalized level a_0 with growth of number of cycles N and also the schedule of cycles variations of the sum D equal to the sum of other components

Notwithstanding what quantity of components increases with each cycle, their average level steadily decreases Processes of redistribution of power between components are rather complicated It results in some oscillation in the curve of the ratio of power of the useful output signal in relation to other components Nevertheless, the power of the useful component increases in average and since some moment this growth is considerably accelerated and the useful signal quickly forces out other components in the output signal

Use of the described method of handing on and signal processing will allow to improve the quality of communication in conditions of the selective frequency fades

References

1 L E Varakin, the communication systems with Noise-like signals, Radio and Communications, Russia, 1985

2 V V Zelensky, Noise Immunity of the Redundant Frequency Modulated Signal Keying Against Harmonic Interference, Radioengineering, Russia No 7 2002

3 L B Milstein, D L Shilling, Proc Isssta, Germany, 1996

4 M E Kamaeva, Y B Sindler, Some Information characteristics of the Means for On-Line-Spectral Analysis of Interferences in Wideband Radiocommunication Systems, Radioengineering and Electronics, Russia No 8, V 48 2003

5 R W Prasad, Wideband CDMA for third Generation Mobile Communication London Artech House, 1998

6 P A Polushin, The Processing of the Multichannel Communication signals as the compactification of the Multidimensional Object in Hilbert Space perspective Technology in the Mass Media, PTMM Vladimir, Russia, 2001

7 P A Polushin, The Matrix Processing of signals Invariant to the Spectral Interferences, Perspective Technology in the Mass Media PTMM 2001, Vladimir, Russia, 2001

8 P A Polushin, The Usage of Entropy Approach to the Elimination of the External Interferences in Commnication Systems, Perspective Technology in the Mass Media, PTMM '1999, Vladimir, Russia, 1999

9 Patent of Russia, No 1628206

10 Patent of Russia, No 1619415