TRANSMISSION OF TIMING INFORMATION BY MEANS OF CONTINUOUS HARMONIC OSCILLATIONS

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The radio stations of the State Time and Frequency Service transmit reference frequencies and precise time signals according to a given program in which the time signals and reference frequencies are transmitted at different times. This makes it impossible either to compare frequencies continuously, or to test and lock-in local chronometers at the required time.

The requirement for a continuous and simultaneous reception of reference frequencies and time signals arises in cases when it is impossible to reproduce the local time scale continuously. Cable communication circuits are widely used for locking-in time scales produced in different places at relatively small (10-100 km) distances from each other.

The limited bandwidth of these circuits reduces the precision in determining the propagation time and leads to considerable errors in timing the received signals.

Below we examine a method which can be used for simultaneously transmitting reference frequencies and time signals along both radio channels and cable circuits.

The timing information is transmitted by means of harmonic oscillations which produce polarized modulation in a single carrier frequency. The phase of one of the modulated oscillations changes continuously with respect to that of the other with a definite velocity, so that the coincidence of phases occurs at definite instants. These instants are made to coincide by means of special devices with the seconds pulses of the local clock and with the zero amplitude of the carrier frequency.

It is known that in oscillations with a polarized modulation, as distinct from a normal amplitude modulation, the positive half periods of the carrier frequency are modulated with one signal and the negative ones with another.

The signals are separated by means of a polarization detector (Fig. 1). Diode D1, which passes positive half periods of the carrier frequency, is intended for selecting one of the signals, whereas diode D2, which passes negative half periods, selects the other signal.

Oscillations with polarized modulation (1 in Fig. 2) can be obtained by adding with a given phase relationship two pulse sequences which have different polarities and are amplitude modulated with different signals.

It is convenient to use as pulse sequences sinusoidal oscillations which are cut off respectively on the positive and negative side of zero amplitude and have a phase difference of \( \pi \). Analytically this can be written as

\[
I_1(t) = \begin{cases} \sin \omega t & \text{for } 0 < \omega t < \pi \\ 0 & \text{for } \pi < \omega t < 2\pi \end{cases}
\]

\[
I_2(t) = \begin{cases} 0 & \text{for } 0 < \omega t < \pi \\ \sin \omega t & \text{for } \pi < \omega t < 2\pi \end{cases}
\]


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If the modulating signals consist of harmonic oscillations with frequencies of $\Omega_1$ and $\Omega_2$, then the positive and negative envelopes of the modulated oscillation can be written in the form:

\[ A_1(t) = A_0 (1 + M_1 \cos \Omega_1 t), \]
\[ A_2(t) = A_0 (1 + M_2 \cos \Omega_2 t), \]

where $A_0$ is the carrier frequency amplitude; $M_1$ and $M_2$ are the modulation factors of the carrier-frequency positive and negative half periods, respectively.

In order to evaluate the spectral composition of an oscillation with a polarized modulation let us expand (1) and (2) into Fourier series, thus obtaining the instantaneous values of the modulated oscillations:

\[ a_1(t) \approx A_0 \left( \frac{1}{\pi} + \frac{1}{2} \sin \omega t - \frac{2}{3} \pi \cos 2\omega t \right) (1 + M_1 \cos \Omega_1 t), \]
\[ a_2(t) \approx A_0 \left( -\frac{1}{\pi} + \frac{1}{2} \sin \omega t + \frac{2}{3} \pi \cos 2\omega t \right) (1 + M_2 \cos \Omega_2 t). \]

By using the superposition principle we can obtain after appropriate trigonometrical operations the spectrum of the resulting oscillations with polarized modulation.

\[ a(t) \approx A_0 \frac{1}{\pi} (M_1 \cos \Omega_1 t - M_2 \cos \Omega_2 t) + A_0 \sin \omega t + \frac{1}{4} A_0 [M_1 \sin (\omega - \Omega_1) t] \]
\[ + \frac{1}{3} \pi A_0 [M_1 \cos (2\omega - \Omega_1) t + M_2 \cos (2\omega - \Omega_2) t] - \frac{1}{3} \pi A_0 [M_1 \cos (2\omega + \Omega_1) t + M_2 \cos (2\omega + \Omega_2) t]. \]

It will be seen from (7) that the spectrum of oscillations with polarized modulation, as distinct from normal amplitude modulation, contains a low-frequency component which represents the difference of the modulating signals.

For further analysis it is convenient to write expression (7) in a more general form as:

\[ U = (U_1 - U_2) + \gamma (U_1 + U_2) \sin \omega t, \]

where $U_1$ and $U_2$ are the modulating signals' envelopes whose shape is determined by (3) and (4); $\gamma$ is the coefficient which determines the fraction of high-frequency components in oscillations with polarized modulation.

It has been noted above that a polarization detector (Fig. 1) can be used for separating the signals in oscillations with polarized modulation. The spectral composition of the output voltage in a polarization detector is determined by the selection of the working point and the inertia of the load.