

PASSIVE METEORIC SYNCHRONIZATION OF TIME SCALES

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Abstract

A special method that allows one to get time and frequency information without radio wave transmission at the secondary point is presented. This method can be used to receive time and frequency information that is contained in the TV signal by a meteor-burst channel.

At the present time, the most widespread and accessible method of time-frequency information transfer (among those using global longwave nets, meteor and satellite systems) is by television.

For transmission of time-frequency information, the standard time-frequency signals (STFS) containing standard frequency signals (SFS), standard time signal (STS), and signals of current time code (CTC) are transmitted in the time slot of the sixth line of the regular extinguishing impulse of each odd TV signal frame. Moreover, the line synchroimpulses (LSP) and frame synchroimpulses of the TV signal are tied to the time scale [1].

To transmit SFS, the first interval of the line with 15 μ s duration is used. SFS are transmitted as signal packets of 1 MHz frequency, an elementary phase of which is tied to television synchrosignals. Because of this, SFS always begin with a positive half-wave of 1 MHz frequency, and its temporal position in relation to impulses of the sixth line is shown in Figure 1. To transmit STS, the second interval of the sixth line with 12 μ s duration is used.

The information about the time scale is carried by the point that corresponds to half of the STS positive front. The repetition frequency of STS is 1 Hz; the duration of positive front is 0,15...0,2 μ s, which corresponds to the maximum bandwidth of the video signal. In order to receive these signals, a special device connected to an ordinary TV receiver may be used. The true time in the receiving point is determined taking into account the TV signal propagation time from television center to receiver.

The basic sources of errors in time scales comparison by TV signals are:

- the measurement error of the time intervals between signals of the local time scale and the received signal (about 20 ns);
- receiving point equipment instability (60 ns);
- determination error of signal propagation time from antenna to the receiving point (10 ns);
- instability of the delay time in the television center's equipment (about 40 ns);
- delay instability in the equipment of the radio relay line, which is approximately equal $0.05 \times N \mu$ s, where N is number of retransmission points of the radio relay line;
- unknown for user delay changes due to channel switching of the radio relay line or its repairs (can bring about errors of more than 1 μ s).

As can be seen from the error source list, the most essential errors are those related to the passing of the TV signal by radio relay lines. The errors increase even more if the signal is transmitted by satellites. This is why we came to the idea of realizing direct TV signal reception from a TV center, eliminating relay lines. It becomes possible due to the meteor-burst radio channel.

The radio wave reflection from meteor trails has been studied sufficiently well and is used for information transmission, and for precision time scale comparison. The precision time scale comparison by meteor-burst channel is performed by the signal propagation time exclusion method – by sending of time signal parcel from the secondary clock standard to the point of the primary standard and its consequent retransmission backward together with the clock signal of the primary standard [2]. This method is based on good reciprocity of the meteor-burst channel (equal time of straight and reverse signal propagation), and it allows synchronization with an error of about 1 ns for distances up to 2000 km [3]. However, to receive such a small error value, one needs sufficiently complicated receiving, processing and, what is very essential, transmitting devices in both points.

The synchronization of time and frequency standards by TV signals does not suppose a signal retransmission in the reverse direction, which is why we do not need to install the transmitting device at the point of the secondary clock. The capital TV centers transmitting the First Program of State Television with time and frequency signals have a sufficiently large power and work in a suitable frequency band (in Moscow on the first frequency channel, in Kiev on the second one, that corresponds to frequencies of 48...66 MHz). This enables direct reception of these signals by a meteor-burst channel. Time-frequency information is contained in each frame of the TV signal and, consequently, is repeated each 20 ms. The typical time duration of a meteor trail channel is from a few tens to a few hundreds of milliseconds, which allows one to receive several hundreds of LSP and several lines containing STFS for a single comparison session. The reception of the CTC and STS will not take place in each comparison session; therefore, it is reasonable to use frame and line synchroimpulses for a rude time scales comparison, and SFS for an exact one.

It is possible that, within 2000 km (maximum meteor-burst signal propagation distance) from the secondary clock site, there are several TV centers. In this case, special identification signals present in 19 lines of the TV signal can be used for differentiation, because they form a 4-digit code unique to each TV center [5].

For the signal propagation by earth wave, the distance passed can be thought equal (with acceptable errors) to the distance between points on the earth's surface. In the case of meteor-burst propagation, the signal path and time delay depend on height and position of each particular trail over which the given synchronization session is performed. If there is no transmitter at point A, then only angular coordinates of the meteor trail can be determined from this point.

These coordinates can be measured by the phase method. For this, in the receiving site a five-aerial antenna system can be used, with aerials situated to make a "cross." Distance between separate aerials should be comparable with the wavelength.

A signal from meteor trail arrives at each of the antennas with delays that depend on spatial position of each antenna. Using the information about the amplitude, phase, and delay time of signal from each antenna, we can determine the angular coordinates of the meteor. This method is used in the Meteor Automatic Radio Location Station (MARS) and allows one to determine angular coordinates of meteors with an error not exceeding 30 minutes of arc [4].

Knowledge of angular coordinates allows one to define its position in space with error that depends on the height of the atmospheric layer within which the meteor trails exist (80...100 km). An error in the determination of position induces an error in finding the delay time equal to the signal propagation time difference on paths AMT and AM'T (Figure 2). In dependence on meteor azimuth (in fact in dependence on angle between directions to transmitting center and to meteor), the difference between AMT and AM'T will be different.

To evaluate the signal propagation time measuring error, a numerical model was created for the meteor-burst radio wave path. The fixed data are: coordinates of secondary point A and signal transmitting point T; height range of meteor trails $H_m = 80\ldots100$ km; the earth's radius $R_0 = 6,378$ km and its equivalent radius (with the refraction included) $R_e = 7,248$ km; and the angular coordinates of meteor trail as seen from point A (zenith angle θ^A and azimuth β^A , measured with errors of 0.5°).

Path geometry computations are performed with the use of relations of spherical geometry and are separated by several stages:

- computations of distance between points A and T on the surface;
- computations of physically realizable zenith angles and azimuths, from which the signals can be received at point A, originating from conditions of "straight visibility" of meteor and antennas parameters at sites A and T;
- computations of distances between points and meteor (M);
- determination of propagation time $t_p(\theta^A, \beta^A)$ and its partial derivatives by angular coordinates $\frac{\partial t_p}{\partial \theta^A}$ and $\frac{\partial t_p}{\partial \beta^A}$.

Modeling results for the Kharkov-Moscow path are presented in Figures 3-6.

If we do not take into account an error determined by the undetermined height of the meteor trail, and consider that all meteors have height of 90 km, then we can note that optimum zenith angles exist at which the signal delay measurement error is minimal. The delay time dependence on angle (in degrees) is shown in Figure 3; delay time dependence on azimuth (in degrees) for different heights is shown in Figure 4; and in Figures 5 and 6 the partial derivatives ($\mu\text{s}/\text{degree}$) for a trail height of 90 km are shown. It can be seen from the figures that for zenith angles less than 10° , the delay time determination error is less than $0.1 \mu\text{s}$, and for zenith angles $10^\circ\ldots40^\circ$, the delay time determination error is less than $1 \mu\text{s}$ if the azimuth determination error is less than 0.5° . The errors are minimal in case of zero azimuth, which is physically impossible because of the meteor-burst propagation properties.

The ambiguity of meteor height (Figure 2) brings about considerable error. This can be seen from delay time dependence on zenith angle and azimuth for different heights (Figures 3 and 4). Such an error can be removed by statistical processing of several consecutive sessions.

The model computations let us state that reception of standard time and frequency signals by meteor-burst radio channels and statistical processing of results can provide a time scale comparison error not exceeding the one from reception of these signals by radio relay line.

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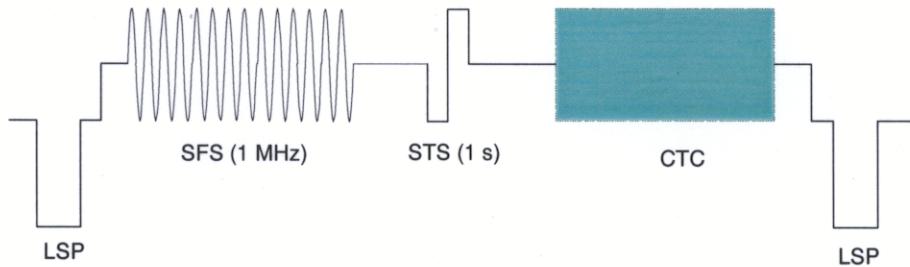


Fig. 1

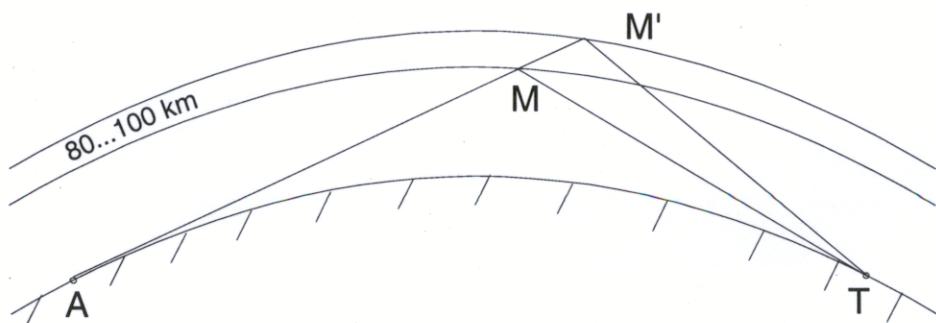


Fig. 2

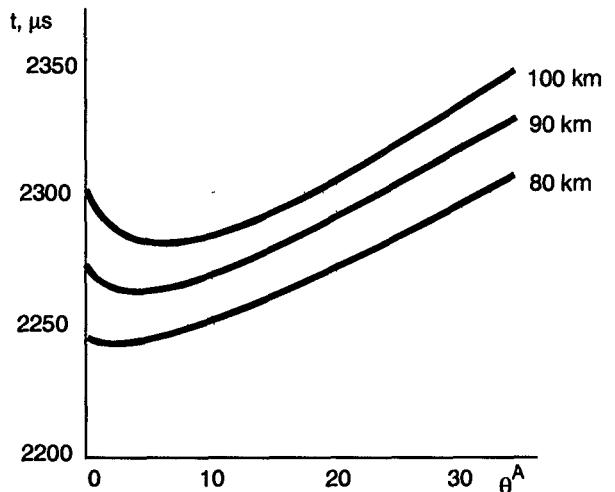


Fig. 3

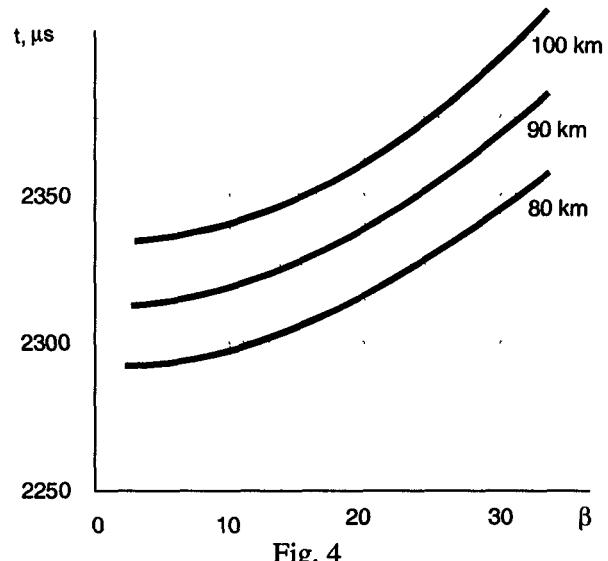


Fig. 4

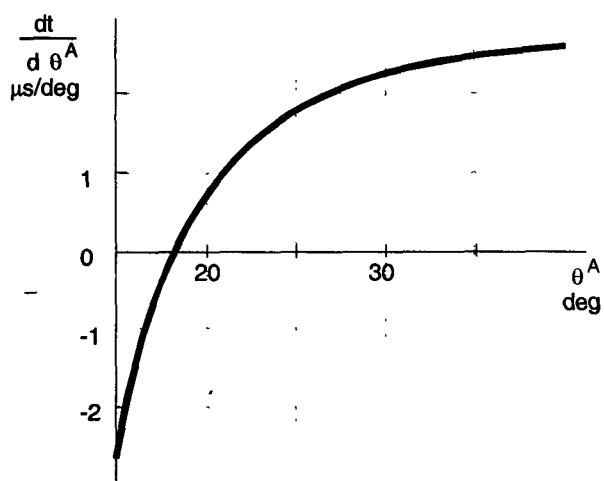


Fig. 5

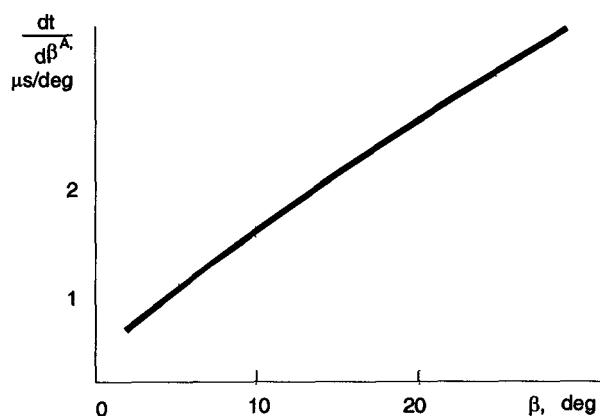


Fig. 6