MODERNIZATION OF METEOR-BURST SYNCHRONIZATION METHOD AND EXTENSION OF ITS APPLICATION FIELD

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ABSTRACT

Special method that allows to get time and frequency information without radiowave transmission at the secondary point is presented. This method can be used to receive time and frequency information that is contined in the TV signal by meteor-burst channel.

Meteor-burst channal, time scale synchronization

Modern digital communication systems require high precision synchronization of generators in network centers. Acceptable frequency instability is about $10^{-11}…10^{-13}$. Frequency synchronization may be achieved using high precision time scale comparison method. The measurement results obtained for separated points make it possible to get the mutual instability of generators:

$$\frac{\Delta f(t)}{f_0} = \frac{d(\Delta T(t))}{dt}.$$

Network standards now contain no recommendations about methods and devises to be used for the necessary stabilization of frequency. This fact allows choosing synchronization method according to technical possibility and local geographical features of the country.

Comparison of different methods of signal transmission shows that for considered problem two possible way of network synchronization exist: global satellite navigation systems (GPS, GLONASS) and meteor-burst communication systems. Meteor-burst method is more precise.

This method is based on high stability and reversibility of the delay time for radio wave propagation due to reflection from meteor trails. Meteor trails arise in the Earth atmosphere at the heights of 80…105 km and provide communication distance up to 2000-2200 km (fig. 1). Duplex time scale comparison method is usually used: the source A and user B get the difference between watches simultaneously. Delay times are equal due to identical radiowave path and can be excluded.

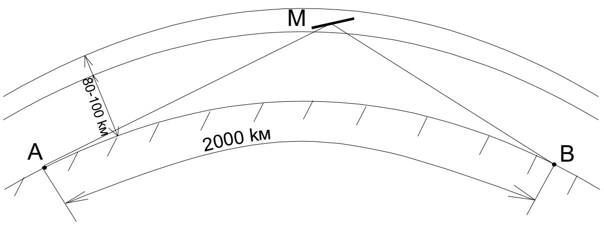

Fig 1

As the advantages of meteor-burst time scale comparison method we can denote the following:

- short time needed to get one measurement result (about 10 s);
- comparatively low cost of design and exploitation of equipment;
- low power consumption,
- equipment can be unattendent;
- secretiveness of comparison seances.

The development of meteor-burst comparison systems have been started in Kharkov (USSR) in 1969 and in the beginning of 70-ies first samples were created (МЕТКА-1, МЕТКА-2). The high precision meteor-burst system for comparison of Russian and Ukraine time standards is in operational work since 1985. This system is equipped with equipment that are designed in Kharkov National University of Radioelectronics. At present time the time scale comparison on the path Kharkov - Moscow is carried out on regular basis, according to Cooperation Agreement of CIS to Provide Unitary Time and Frequency.- Refs. 1,2.

Main disadvantage of this method is the need of radio wave emission in both points of measurements. The working frequency is usually 40...60 MHz.

The time comparison equipment can be easily mounted in any chosen point. This allows comparing between local time-frequency standards and State Standards with accuracy about 1 ns.

For 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 a television method.

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 sixth line of regular extinguishing impulse of each odd TV signal frame. Moreover, the line syncroimpulses (LSP) and frame syncroimpulses of TV signal are tied up to time scale.

To transmit SFS, the first interval of line with 15 μs duration is used. SFS are transmitted as signal packets of 1 MHz frequency, an elementary phase of which tied up to television syncrosignals. Because of this SFS always begin with positive half-wave of 1 MHz frequency, and its temporal position in relation to impulses of sixth line is shown on fig. 4. To transmit STS the second interval of sixth line with 12 μs duration is used.

The information about 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 μs, that corresponds to maximum bandwidth of videosignal. In order to receive these signals a special device connected to an ordinary TV receiver my 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 time intervals between signals of local time scale and 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 centers equipment of (about 40 ns);
- delay instability in the equipment of radiorelay line, that is approximately equal $0.05 \times N$ μs, where N is number of retransmission points of radiorelay line;
- unknown for user delay changes due to channels switching of radiorelay line or their repairs (can bring about errors of more than 1 μs).

As can be seen from error source list, the most essential errors are those related to passing of TV signal by radiorelay lines. The errors increase even more if the signal is transmitted by satellites.

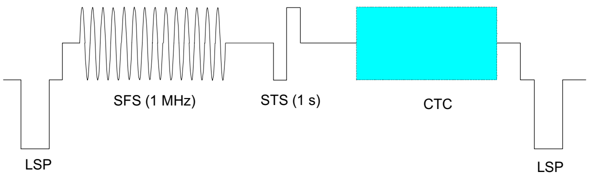

Fig. 4 - Time and frequency signals in sixth line of TV signal

That's why we come to idea to realize direct TV signal receiving from TV center, eliminating relay lines. It becomes possible due to meteor-burst radio channel.

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

It's 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 line of TV signal can be used for differentiation, because they are forming 4-digit code, unique for each TV center.

For the signal propagating by Earth wave the distance passed can be thought equal (with acceptable error) to the distance between points on the Earth surface. In 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 in point *A*, then only angle coordinates of meteor trail can be determined from this point.

These coordinates can be measured by phase method. For this in receiving site a five aerials antenna system can be used, with aerials situated to make a "cross". Distance between separate aerials should be comparable with wavelength (fig. 5).

To evaluate the signal propagation time measuring error the numerical model was created for the meteor-burst radiowave path. The fixed data are: coordinates of secondary point A and signal transmitting point B*;* height range of meteor trails $H_m = 80...100$ km; Earth radius $R_0 = 6378$ km and its equivalent radius (with the refraction included) $R_e = 7248$ km*;* the angle coordinates of meteor trail as seen from point A (zenith angle θ^A and azimuth β^A , measured with errors of 0.5°).

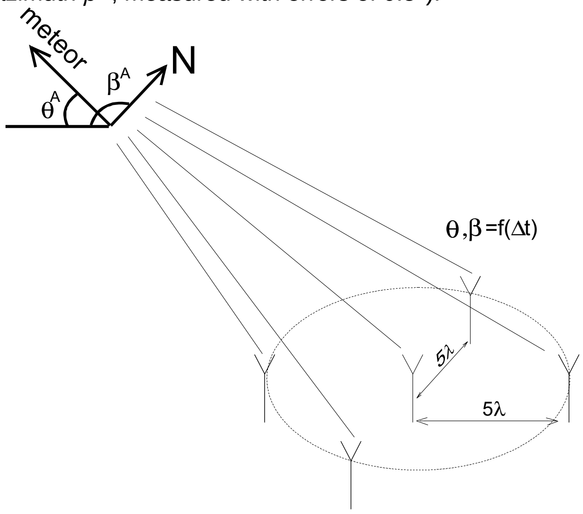

Fig. 5 – Antenna system for determinaton θ and β

A signal from meteor trail arrives at each of antennas with delays that depend on spatial position of each antenna. Using the information about amplitude, phase and delay time of signal from each antenna we can determine the angle coordinates of meteor. This method is used in the Meteor Automatic Radio Location Station (MARS) and allows to determine angle coordinates of meteors with error not exceeding 30 angle minutes – Ref. 3.

Knowledge of angle coordinates allows to define its position in space with error, that depends on height of atmospheric layer, within the meteor trails exist (80...100 km). An error in determination of position induces an error in finding the delay time, equal to signal propagation time difference on paths BMA and BM'A (fig. 6). In dependence on meteor azimuth (in fact in dependence on angle between directions to transmitting center and to meteor) the difference between BMA and BM'A will be different. Path geometry computations are performed with the use of relations of spherical geometry and are separated by several stages:

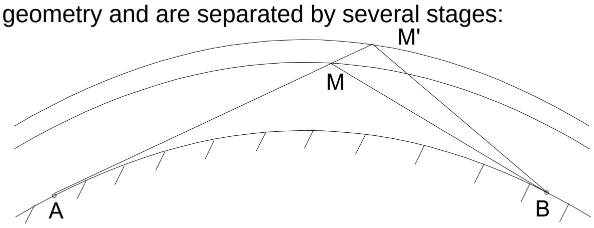

Fig. 6 - Undetermination height of meteor trail

- computations of distance between points A and B on the surface;

- computations of physically realizable zenith angles and azimuths, from which the signals can be received in point A, originating from conditions of "straight visibility" of meteor and antennas parameters in sites A and B;

- computations of distances between points and meteor (*M*);

- determination of propagation time $t_S(\theta^F, \beta^F)$ and its partial derivatives by angle co-ordinates $\frac{\partial t_A(\theta^A,\beta^A)}{\partial \theta^A}$ and $\frac{\partial t_ð(\theta^À,\beta^À)}{\partial \beta^À}$.

Modeling Results for Kharkov-Moscow path are presented on fig. 7 – 10.

If we do not take into account an error, determined by undetermined height of meteor trail, and consider that all meteors have height of 90 km, then we can note that optimum zenith angles exist, at which signal delay measurement error is minimal. The delay time dependence from angle (in degrees) is shown on fig. 7; delay time dependence from azimuth (in degrees) for different heights is shown on fig. 8; and on fig. 9 and 10 the partial derivatives (µs /degree) for trail height of 90 km are shown. It can be seen from figures, that for zenith angles less than 10° the delay time determination error is less than 0.1 µs, and for zenith angles 10°…40° the delay time determination error is less than 1 µs if the azimuth determination error is less than 0.5°. The errors are minimal in case of zero azimuth, that is physically impossible because of the meteor-burst propagation properties.

The ambiguity of meteor height (fig. 6) brings about considerable error. This can be seen from delay time dependence on zenith angle and azimuth for different heights (fig. 7 and 8). Such an error can be removed by statistic processing of several consequent sessions.

The model computations let us state that receiving of standard time and frequency signals by meteor-burst radio channel and making the statistic processing of results can provide a time scale comparison error not exceeding the one from receiving of these signals by radiorelay line.

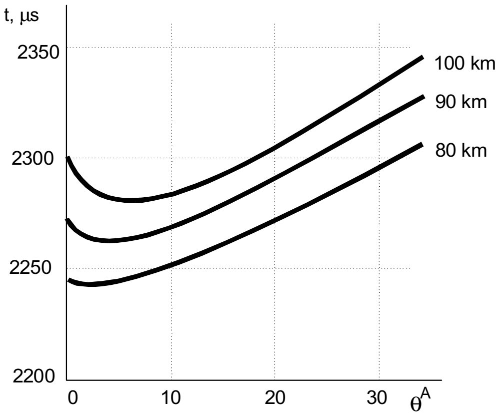

Fig 7

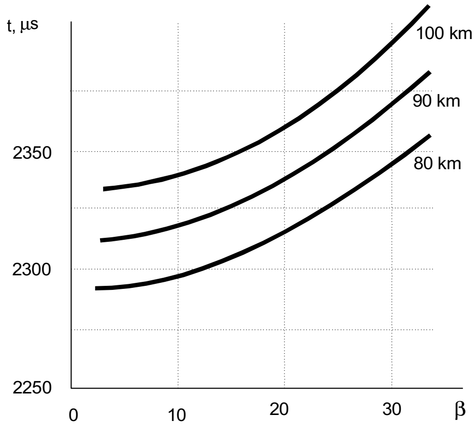

Fig 8

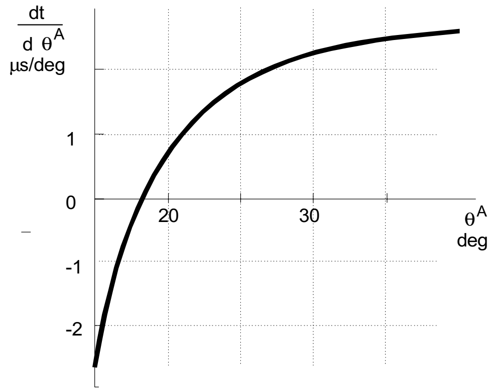

Fig 9

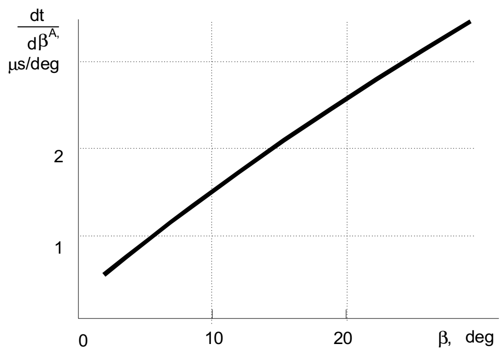

Fig 10

REFERENCES

1. Мник Б.С., Кащеев Б.Л., Лейкин А.Я. Использование метеоАного АаспАостАанения Аа'иоволн 'ля пАивязки часов пМнктов слМжбы вАемени и частоты. ИзмеАительная техника. 1971. N 12. С. 38-42.
2. Кащеев Б.Л., Бон'аАь. Б.Г., ГоАбач В.И., Коваль Ю.А. МетеоАы сего'ня. Киев: Техніка, 1996. 196 с.
3. Кащеев Б.Л., ЖМков В.В. Автоматический МгломеА. Сообщение 1. ПАинципы постАоения / В кн. Ра'иотехника. Вып. 47. ХаАьков. 1978. С. 3-9.