INSTRUMENTAL CHECKING OF CERTAIN INSTRUMENT ERRORS OF PHYSICAL-GEODETIC TELEMETERS

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Introduction

In the present practice, geodetic-physical telemeters commonly are being checked on geodetic bases or in test networks. This method is too expensive and hardly permits to separate the sources of errors. Therefore, laboratory instrumental checking grows in significance, permitting the separation of the sources of errors, their determination under service conditions as well as the improvement in precision of the distance measurements. Further, the practical experience shows, after factory adjustment of the parameters, an ever increasing necessity of field checking the instruments in service, widening the range of laboratory tests. To this aim, laboratory testing of physical telemeters has been started with at the Department of Survey, the first results of which are presented in this paper.

Electric parameters of the most frequent physical telemeters were to be examined. As a starting point it was adopted that the precision of telemetry absolutely depends on the precise measuring frequency and the required precision of phase determination. The frequency error is given by the relationship:

$$\Delta D_f = -\frac{\Delta f}{f} D$$

and the usual crystal controlled oscillators exhibit a precision of 10^{-6} to 10^{-7}.

The phase determination error is expressed by:

$$\Delta D_r = \frac{\lambda}{2} \frac{\Delta \varphi}{2\pi}$$

and the usual precision of the phase reading is 0.2° to 1.0°. This relationship shows the telemetry error to depend also on the wavelength of the frequency adopted.

For finding a solution to the above problem, a new test method has been developed, likely to be used as starting basis in checking any type of physical telemeters.

Evaluation of frequency and phase determinations

In our direct determinations, the precision of our instruments was at least by an order of magnitude higher than that of the frequency and phase to be determined. Accordingly, the results correspond to the concept of the random variables, the values being independent and showing a random variation. There being only a few results available, so in our study the Student t distribution has been applied, stating that for n results available, the value to be expected from determinations is the arithmetic mean of the random variables:

$$\bar{\eta} = \frac{\eta_1 + \eta_2 + \ldots + \eta_n}{n}$$

The reliability interval around the value expected is

$$\bar{\eta} \pm t \frac{s}{\sqrt{n}}$$

wherein s = corrected empirical scatter (i.e., mean error)

$$s = \frac{\sum_{i=1}^{n} [\bar{\eta} - \eta]^2}{n - 1}$$

t = quantity associated with the different probability standards:

$$(p)\, t = \frac{\Gamma\left(\frac{n}{2}\right)}{\sqrt{(n-1)\pi}\,\Gamma\left(\frac{n-1}{2}\right)} \int_{-\infty}^{0} \left(1 + \frac{t^2}{n-1}\right)^{-\frac{n}{2}} dt.$$

In evaluating the results, we applied the probability standard $p = 90\%$ used in the electronic industry.

Further, the preassumption was examined that the limit distribution of the Student t distribution (the normal distribution) arises from taking the random variables found under identical conditions one by one and transform them into standardized random variables. In our case, the above assumption has been justified.

Processing of frequency data of the light telemeter NASM-6, for a probability standard of 90%, has led to a reliability interval of ± 1.5 Hz to ± 5.0 Hz, whilst with the microwave telemeter GET-B1, a reliability interval of ± 0.6 Hz to ± 1.4 Hz was obtained. The above values justified the correctness of the determination method for the frequencies of $\cong 30$ MHz and 10 MHz, respectively.

In tests on the phase determination system of the microwave telemeter GET-B1, for a probability standard of $p = 90\%$, we obtained a reliability interval of $\pm 0.1°$.

In evaluating the frequency data, the conclusions are expressed in mm of error for each km of distance. Thus, in case of the microwave telemeter GET-B1:

$$\Delta D_{\mathrm{mm/km}} = \frac{\Delta f[Hz]}{10},$$

and in case of the light telemeter NASM-6

$$\Delta D_{\mathrm{mm/km}} = \frac{\Delta f[Hz]}{30}.$$

Frequency checking and calibrating the physical telemeters

In order to minimize the measurement errors with physical telemeters, it is recommendable to systematically check and calibrate the frequency of the instruments, with due consideration to the reproducibility, the maximum

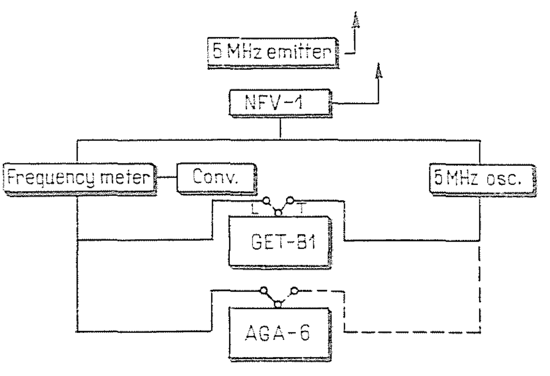


Fig. 1

distinction of errors, checks as frequent as required, and the precision requirements. A great care was needed in establishing our measurement methods since the frequency had also to be checked in the field.

Our measurement system, schematically presented in Fig. 1, was based on a reference frequency of 5 MHz, emitted by the Hungarian Post and checked by the National Office of Metrology. A receiver, specially developed at the Department of Survey for the reception of this transmission has a comparison circuit for directly comparing the measuring instruments. With the frequency meter adopted, a precision of 10^{-7} to 10^{-8}, depending on the gauging time, could be obtained for frequencies up to 120 MHz, which is at least by an order of magnitude higher than that of the oscillators of the actual physical telemeters. Though the same frequency meter with a separate aggregate was used under field conditions, in such cases it was advisable to apply a battery-operated quartz oscillator of a precision of 10^{-7}/month. The dashed line in the figure refers to the intended use of this oscillator for calibrating the light telemeter NASM-6, by producing adequate measuring frequencies.

The measuring frequencies of the microwave telemeter GET-B1 have been branched off the output terminal of the telephone, which permits an inductive coupling without reaction on the output of the measuring oscillator. In case of the light telemeter NASM-6, again by inductive coupling, the separation of the signal without reaction was assured from the output of the power amplifier.

Evaluation of the frequency determinations

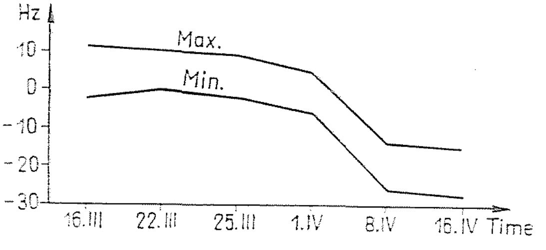
Frequency determinations involved checking of the measuring frequencies of physical telemeters against the supply voltage, the time and the interval from switching on, as well as the examination of errors occurring in the field application of the instrument.

Time-dependent checking of the crystal controlled oscillator of the light telemeter NASM-6 has four times been repeated. Each series of measurements lasted a month, and within this period the measurements were six times repeated under laboratory conditions, taking into account the requirements of the practical application, therefore measurements were made in four different times each day. At each occasion, two values, 20 and 30 minutes after switching in, were considered. Diagrams were plotted to evaluate the deviation of anticipated frequency maxima and minima from the eight measurements per day (due to the change of the thermostated temperature) from the normal frequency. This is illustrated by the diagram in Fig. 2 representing one test series on the oscillator U_1. Results perfectly in agreement were obtained on the other two oscillators. Analysis of test series showed a frequency decrease by 25 Hz during a month, under unchanged external conditions, likely to produce an error of 1 mm/km.

It was interesting to test frequency changes as a function of the time passed since switching on. In conformity with our previous practice, between two series of measurements at least 50 minutes of interval were left from switching off to on and only the first 20 minutes after switching on was taken into account. The obtained results are presented in Fig. 3, comparing the variation during the first 20 minutes to the value expected after 20 minutes. Even after the first 10 minutes a difference of 23 Hz is seen to occur causing an error of

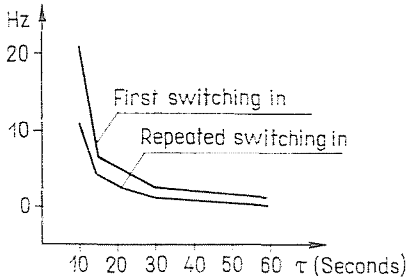
1 mm/km. Accordingly, time component should be selected in dependence of the precision. The presented test results for the oscillator U_1 equal those on the two other ones. Since, however, the distance measurements started with the oscillator U_1, this one was to be presented.

The light telemeter has a fairly stable supply voltage; in the required range no deviations of frequency were observed. At the same time, however, between frequency maxima and minima of the oscillators, differences of 10 to



Zero value corresponds to 29 970 000 Hz

Fig. 2



Zero value corresponds to 10 MHz

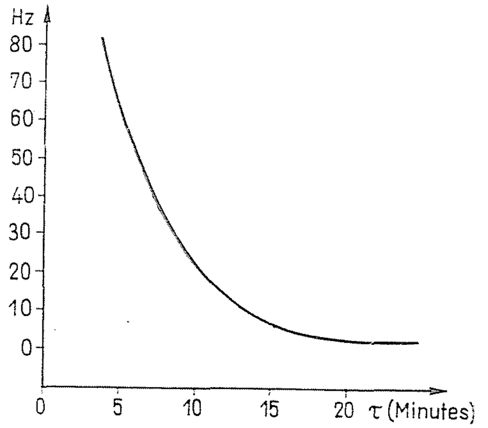
Fig. 3

20 Hz occurred upon change of the thermostated temperature. Considering that in field checks differences as high as 30 to 35 Hz were observed, errors of nearly 1 mm/km may arise. This fact may lead to the excess of the permissible limit of error; therefore, in order to minimize the errors, the number of the frequency checks should be increased. Further tests are required by the frequency differences of 25 to 35 Hz between laboratory and field measurements, the physical derivation of which has not yet taken place.

Test results on the crystal-controlled oscillators of the microwave telemeter GET-B1

From the test method of the telemeter definitely follows that the oscillator of 10 MHz, necessary for precision, has to be tested. Test results showed in two months an average frequency decrease of 8 Hz corresponding to an error of nearly 1 mm/km in distance measurement. Evaluation of the data was based on values found 30 minutes after switching on. Throughout the test period, four measurement series have been carried out a day with intervals of 1 to 1 1/2 hours between switching off and on.

The time τ from switching on was considered by taking into account whether the instrument was heated up the day of testing or not (Fig. 4). $\tau = 15$ min is seen to be needed for the frequency difference as compared to that 30 min after switching on not to exceed 4 to 5 Hz, corresponding to an error of 1/2 mm/km.



The value of 0 frequency corresponds to the expectable value after 20 minutes

Fig. 4

The frequency deviation of the oscillator has been checked in function of the change in supply voltage and temperature of the thermostat. The maximum deviation did not exceed 2 Hz in any case.

Field checking of the instrument also produced satisfactory results; the maximum difference between laboratory and field tests was 2 to 4 Hz.

From the above statements it may be concluded that frequencies of telemeters NASM-6 and GET-B1 are advisably checked each two to four weeks, and in every one or two months, respectively, or, if necessary, recalibrated.

Owing to the rather low basic error of the light telemeter NASM-6 in measuring long distances, the error may significantly be reduced by decreasing the frequency deviations, possible also by increasing the number of frequency checkings.

Checking the phase-metering system of physical telemeters

All of the methods known so far from the literature derive their conclusions on the error of phase indication from gradual distance measurements. This system, however, gave only information on measurements carried out on standard lines and under identical conditions. Otherwise, informations failed to consider systematic inside and outside reflections, climatic changes, and to separate the error in phase indication from the other ones.

To avoid this, a measuring method especially suitable for the independent investigation of high precision of the error in phase measurement has been developed.

Measurements were made under laboratory conditions assuring perfect reproducibility.

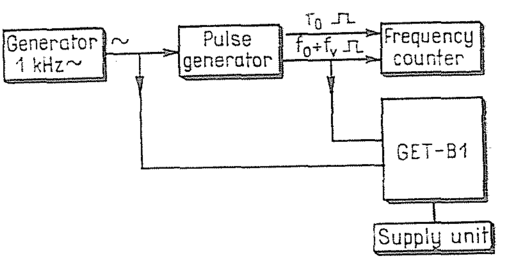


Fig. 5

This method is suitable for testing the base system of any physical telemeter type.

In our laboratory, the phase-meter of the microwave telemeter GET-B1 was experimentally checked.

The test arrangement is shown in Fig. 5. The sine signal of 1 kHz is taken off a decade generator with systematically checked frequency. The sine signal of 1 kHz is input to the phase meter as a base signal to be extincted in comparison with its 0-transition by an impulse dephased by $\varphi_0 + \varphi_v$. The telemeter is fed from an external supply unit because the converter of the instrument oscillates at about 1 Hz, likely to introduce an additional error into the phase measurement. Phase measurement more precise by an order than the previous ones is realized by the frequency meter gating with the impulses φ_0 and $\varphi_0 + \varphi_v$.

Of course, measurement should be preceded by the determination of dephasing φ of the impulse generator with respect to the zero-transition.

The whole phase angle 2π of the signal may be checked as frequently as required, with the help of the dephaser incorporated in the impulse generator. At the same time, the effect produced by the signal amplitude on the phasemeter may be investigated.

In elaborating the test method, the non-linear distortion of the medium frequency amplifier and of the amplitude demodulator was omitted because the resulting phase errors could not be considered as errors in the phase-comparing system. At the same time, as known from the literature, distortions caused by the harmonics take part in producing certain distortions of higher than elliptic order. This error may be examined by placing a suitably calibrated distorting unit before the instrument.

After laboratory testing the essential parts of physical telemeters, further investigations on the high-frequency block, the effect of inner reflection of the aerial system and of the demodulators of light telemeters on the phase measurement for microwave telemeters seem to be necessary.

Summary

The Department of Survey of the Budapest Technical University developed a method for checking the major electric parameters of physical telemeters. The method is featured by permitting under laboratory conditions to separate sources of errors, to systematically check the factory parameters and consequently, to upgrade the precision of telemeters. The method has been applied to check and calibrate the light telemeter NASM-6, and the microwave telemeter GET-B1.

References

OTIS, A.: Kontrol etalonikh chastot elektromagnetnikh dalnomerov. Institut po Geodesii a Kartografii. Warsaw, 1967.

Anleitung zum Geodimeter-Instrument Modell 6. AGA Aktienbolag 1965.

BEIER, E.: Die Variation der Nullpunktkorrektur des PEM2 in Abhängigkeit von der Ablesestelle an der Oszillographenröhre. Vermessungstechnik 1968.

CSATKAI, D.: Electric telemeters and their application in survey. (In Hungarian.) Institute of Post-Graduate Engineering Education, 1966.

DRAHEIM, H.: Die elektronische Entfernungsmessung auf der XIV. Generalversammlung der IUGG. Allg. Verm. Nachrichten 1968. Jan.

ÉLTETŐ, Ö.—L. ZIERMANN M.: Mathematical Statistics. (In Hungarian.) Budapest, 1964.

Frequency-meter applications on up-to-date physical telemeters. Report of the Department of Survey of the Technical University, Budapest, to the Hungarian Surveying Board, 1968. (In Hungarian.)

Microwave geodetic telemeter, type GET-B1. Detailed description and operation manual. Finommechanikai Vállalat, Budapest. (In Hungarian.)

IVANOV, I.: Über eine Möglichkeit zur Lösung des Problems der Bodenrefraktion bei Radioentfernungsmessungen. International Conference on Geodetic Measurements and Instruments. Budapest, 1966.

MEINKE-GUNDLACH: Radiotechnisches Handbuch. 1961.

ROSE, W.: Erfahrungen mit dem Geodimeter Modell 6. Allgemeine Vermessungsnachrichten Jan. 1968.

Tests with Up-to-date Physical Telemeters. Report of the Department of Survey of the Technical University, Budapest, to the Hung. Surveying Board. 1968. (In Hungarian.)

YASKOVICH, I. A.: Tellurometer Zero Error Electromagnet. Distance Measur. London, Hilger and Watts, 1967.

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