OBSERVATIONS WITH THE CA-1000 MICROWAVE TELEMETER*

By

E. Farkas

Research Laboratory of the Institute of Geodesy, Surveying and Photogrammetry,
Technical University, Budapest

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Since their first appearance 30 years ago, microwave telemeters have proved their suitability in geodesy. In Hungary, microwave telemeters have been applied since 15 years, the serial production of GET-B1, stressing the relating research work. This program has been shared by the Institute of Geodesy, Surveying and Photogrammetry, experimenting with microwave equipment for years. Recent promising experiments have been concerned with telemeter types GET-A2 and CA-1000. Investigations made with this latter will be described below, together with some suggestions on its adaptation.

CA-1000 manufacturer's (Tellurometer Co.) data:
Mean square error of distance measurement by CA-1000 = $\pm(15 + 5.10^{-6}D)$mm

Range: short range horn	10 km
long range horn	30 km
Measuring frequencies	19 to 25 MHz
Accuracy of frequency	better than 5.10^{-6}.

Experiments aimed at checking these data, at an eventual improvement and at the adaptation of the instrument for Hungarian conditions.

In Hungary, use of the telemeter type CA-1000 has been suggested primarily for improving the accuracy of the geodetic horizontal control net and the economy of the determination of new control nets. In lack of a Hungarian test net, this was achieved, in addition to laboratory measurements, by re-measuring some distances in the existing third-order triangulation net.

Our laboratory tests concerned the inaccuracy of measuring frequencies, an important component of the errors of microwave telemeters. Frequency variation of the CA-1000 signal vs. switched-on time, temperature and feed voltage has been investigated.

CA-1000 telemeter is featured by an unthermostated crystal oscillator, raising doubt to the manufacturer's instruction to ignore stabilization time.

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Therefore our laboratory tests involved the switching-on phenomenon at various temperatures (Fig. 1). At a difference to the manufacturer's instruction, neglect of the switching-on phenomenon proved to be only admissible in the temperature range from +12.5 to +33 °C, while low (−3 °C to +12.5 °C) and high (+33 °C to +43 °C) temperatures imposed a waiting time of 4 to 5 min before the oscillator got stabilized. At still lower temperatures, e.g. −8 °C, the oscillator did not get stabilized even after 7 min.

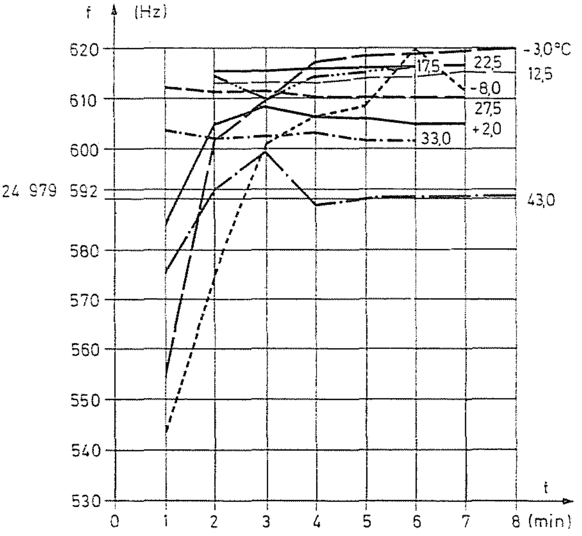

Fig. 1

Feed voltage-dependent variation of the crystal oscillator frequency of the instrument was checked at different temperatures (Fig. 2), showing above +12.5 °C the instrument stabilizer to behave as well as indicated by the manufacturer, hence to be practically indifferent to feed voltage variations. But also here, at lower temperatures (e.g. +2 °C) the feed voltage variation has to be reckoned with, it being susceptible of an error as high as 1 mm/km.

Temperature dependence of the measuring frequencies of telemeter CA-1000 has been tested both in dry and in humid atmosphere (Fig. 3). The unthermostated crystal oscillator was found to be fairly compensated, the maximum error of 32 Hz in the test range was within the tolerance.

The accuracy of the crystal oscillator frequency can even be improved compared to the manufacturer's data by taking its deviations at different temperatures into consideration.

Our laboratory measurement results have been compiled in Table I. Involving them in field measurements improves the accuracy given by the manufacturer for the instrument.

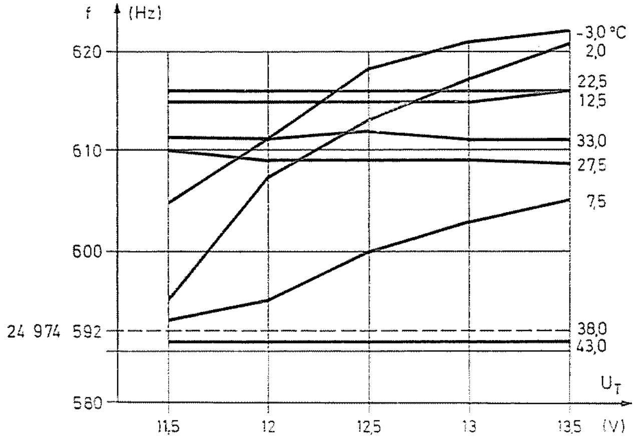

Fig. 2

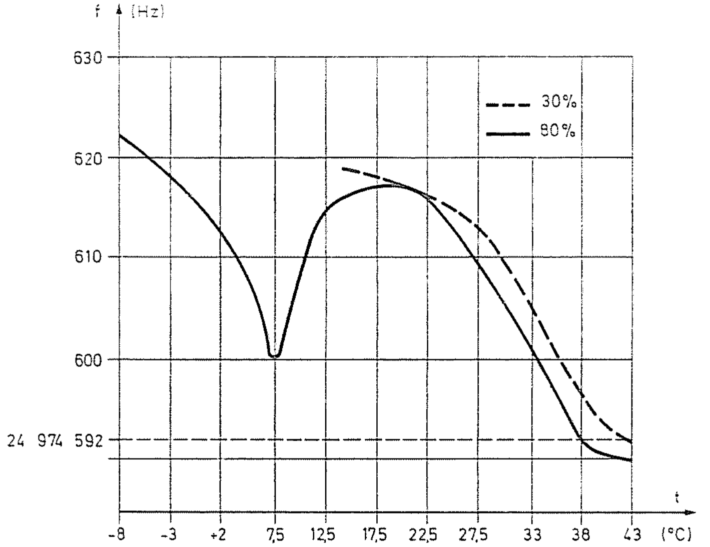

Fig. 3

Table I

T °C	—8—0	0—4	4—10	10—12	12—24
Correction mm/km	1	0.8	0.5	0.8	1
T °C	24—28	28—32	32—34	43—38	38—44
Correction mm/km	0.8	0.6	0.4	0.2	0

Mean square error m of distance measurement by microwave telemeters is much affected by the determination error of instrument constant A_k enhancing the care to be applied in A_k determination measurements, with a special consideration to the inherent errors of determining the atmospheric refraction index, of the frequency, the test control net inaccuracy, and these due to reflection. To increase the versatility, and to deduce consequences for the adaptation, the microwave telemeter CA-1000 has been tested in several regions of Hungary, such as in the *Cserhát* Mountains, accompanied by simultaneous measurements on the third-order trigonometric net done by the Budapest Geodetic Co. using an electro-optical telemeter type AGA-6/A.

Without entering in details, from the comparison of telemeter efficiencies it appeared that while in unfavourable meteorological conditions electro-optical telemeter AGA-6/A had a range as short as 2.7 km, CA-1000 exhibited a much greater spectrum amounting to ten distances averaging 5 km.

Three measurements on the third-order net and other three measurements done in *Recsk* and *Balatonkenese* under the same conditions as above, have been compared to those made by the electro-optical telemeters (Table II). The six data gave an average instrument constant $A_k = 37$ mm, with a mean square error $m = 15$ mm, better than the manufacturer's data.

Our tests unambiguously supported the suitability of the examined microwave telemeters, as well as their practical use and economic efficiency. As a matter of fact, characteristics of the type CA-1000 corresponded to the manufacturer's data, and showed utility in Hungarian conditions. Upon adaptation, measurement results can still be improved. This work is going on, and even some improvements can be stated (see Tables I and II). Further improvements are likely upon the following modifications, suggested by the Institute of Geodesy, Surveying and Photogrammetry, for the next year:

a) modification of the telemeter antenna system, reducing the beam angle to 5 to 7° likely to reduce reflexion errors, at the same time to increase

Table II

Station	Sighting point	Slope distance m	Slope distance m	Deviation mm	Value improved by CA-1000 instrument constant	Residual deviation mm
Third-order points		CA-1000	AGA-6/A			
421—12	324—11	2745.166	2745.124	+42	2745.129	+ 5
316—10	316—11	4907.169	4907.121	+48	4907.132	+11
414—14	414—02	6278.196	6278.187	+ 9	6278.159	—28
RECSK			EOS			
109	105	2361.495	2361.454	+41	2361.458	+ 4
			EOK-2000			
105	106	1184.258	1184.226	+32	1184.221	— 5
BALATONKENESE			EOS			
Hosszúmező	Sérhegy	4115.310	4115.258	+52	4115.273	—15

the telemeter range to at least 40 km, making it suitable for first-order geodetic net measurements;

b) creation of a test net permitting to determine the instrument constant at a higher accuracy;

c) construction of a tube feed line system permitting to distinguish inherent instrumental errors from outer disturbances in laboratory conditions;

d) in view of the appearance of programmable pocket calculators, development of programs permitting field evaluation at an increased accuracy. (Sinusoidal approximation of the swing curve has already been developed for pocket calculator HP-65);

e) last but not least — in agreement with observations made by the research team of the Karlsruhe University — determination of meteorological data prevailing at terminals, at least 10 m above earth surface likely to improve the reliability.

Summary

In geodetic practice, recently preference has been given to electronic geodetic instruments, in particular, to microwave telemeters, of them type CA-1000, actually manufactured by Tellurometer Co., has been investigated. Laboratory tests have been made on the dependence of the stability of crystal oscillator frequency on switched-on time, temperature and feed voltage. The CA-1000 telemeter has been compared to electro-optical telemeters applied on third-order control nets. Finally, some suggestions are made, likely to increase measurement accuracy.

Dr. Ervin FARKAS, H-1521 Budapest