TESTING DYNAMIC MOTION OF A BODY WITH A GIVEN SURFACE

E. FARKAS—GY. GRACZKA

Institute of Geodesy, Technical University, Budapest, H-1521

(Received: March 2, 1981)

Presented by: Prof. Dr. Ferenc Sárközy, Director

The *Laboratory of the Institute of Geodesy, Technical University, Budapest* faced a unique problem: evaluation of static and dynamic motions of a parabolic aerial.* (See A. KRAUTER on a geodetic method for finding form and deformation of a given surface in this issue.) The involved dynamic motions were much faster than those usual in geodetic practice, imposing to develop measuring methods that were new compared to devices and experience available to us.

Dynamic motions of extended bodies can be measured by inductive transmitters (at a relatively high accuracy). But at that time the Laboratory of the Institute had no such instrument, therefore first a new method had to be developed. Finally, three different but complementary methods involving laser beams arose. Performing the measurement with each of the three, the results — besides of testifying the practicalness of the methods — have led to more complex conclusions than did those of the methods known to now.

The first method was adapted to the laser beam and the peculiar rough surface of the given parabolic aerial, thus the arising dynamic motions could not be measured else than by the laser beam and a mirror placed on the aerial. The procedure consisted in mounting little mirrors at several points of the parabolic aerial (Fig. 1), having no influence on its state of motion but taking all the motions at the investigated spot. Thereafter from a laser emitter at a fixed place, independent of the aerial, a beam was aimed at the mirror, to sense the vibration of the aerial by means of the reflected light. Then a dynamic force caused the aerial to vibrate, thus the signal i.e. the light beam reflected by the mirror moving together with it could be received by an active detector. This signal, proportional to the dynamic motion of the aerial, was evaluated by a signal form analysing system, as follows.

First of all, the signal — changing slower than electrical signals do — had to be shaped for ease of handling and storage using an analog-digital

* Testing the dynamic movement was expected a possibly exact knowledge of the state of motion of the vibrating body, the determination of the fundamental mode and the upper harmonics, as well as of the damping coefficient.

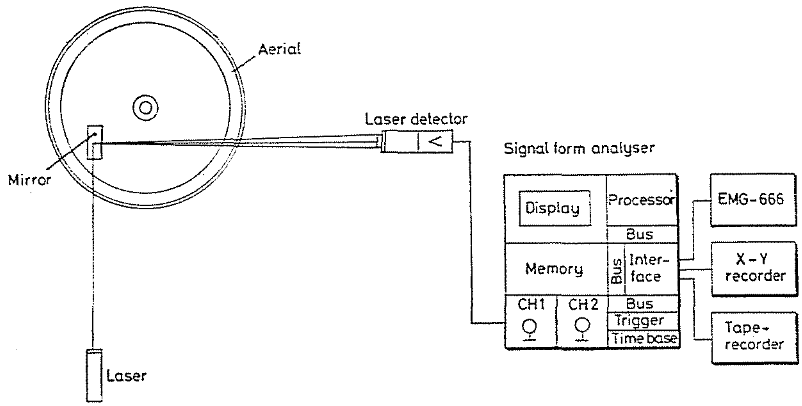

Fig. 1. Layout scheme of the light detector test

converter. To obtain a result independent of the transient phenomena due to force effects on the aerial, at the first instant a time lag has to be introduced. The reference time has to be selected to be at least twice the period of the highest harmonics to be considered. The obtained signal is recorded in digital form in the semiconductor memory of 4×1 *k*byte. To carry out measurement series again and again, digital information is put to magnetic data storage as background memory. Evaluation is made by returning the information from the background memory to the semiconductor memory each 4 *k*byte, i.e. each measurement series, to be processed mathematically by an analyser connected to an *Intel* 8080 microprocessor. Fourier expansion of the measurement signal:

$$f(t) = F_0 + \sum_{k=1}^{n} F_k \sin(k\omega t + \varrho_k)$$

gives adequate information about the arising harmonics and their amplitudes. Vibration damping is characterized by the logarithmic ratio of the fundamental mode amplitudes:

$$a = ln \frac{F_1'}{F_1''} .$$

The measured signals were recorded by the $X-Y$ plotter of the analyser system. Such a diagram containing 1 *k*byte information is seen in Fig. 2. The signal of the fundamental mode of about 15 Hz with the maximum amplitude is clearly visible. To eliminate noises biasing the detected signal, the signal shape was smoothed by the following mathematical operation:

$$D_0 = \frac{2d_0 + d_1}{3}$$

$$D_i = \frac{d_{i-1} + 2d_i + d_{i+1}}{4}$$

$$D_{1023} = \frac{d_{1022} + 2d_{1023}}{3}.$$

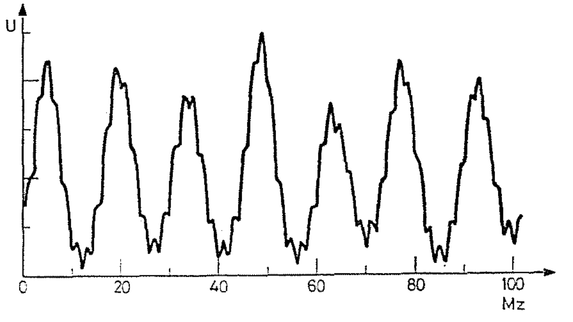

Fig. 2. Dynamic testing of aerial by means of a signal form analyser

Also this result has been recorded by the $X-Y$ plotter (Fig. 3) to clearly show also the third harmonic of about 45 Hz with a smaller amplitude.

The same measuring method was used to simultaneously evaluate signals from two different sources, to investigate vibrations at two different points of the aerial.

The mirrors were first placed at 90° to the aerial axis, then diametrally, and the signals were guided by two independent laser detectors to the input of the analyser.

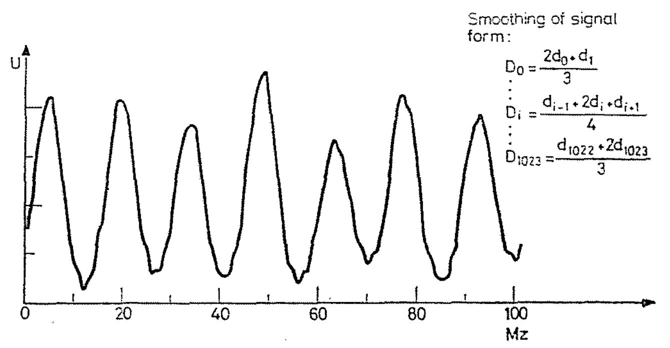

Fig. 3. Dynamic testing of aerial with signal form analyser

This method was applied in many measurement series and comparison showed rather similar dynamic motions to arise at every point of the aerial, hence in this case the method of one signal light source is quite enough.

The idea of the second measurement method was based on the principle of positive feedback, current in electrical engineering: a system (Fig. 4) is self-excited at its resonance frequency. Purpose of the measurement was to determine the fundamental mode of the aerial body from the upper harmonics. For this test the aerial was excited by a short-time dynamic force effect. The damped vibration of the body was transformed to an electric signal by means of a pickup, then amplified by an amplifier with a high-pass wave filter and fed to a dynamic loudspeaker. Waves developing in the air space between the loudspeaker and the vibrating aerial at the resonance frequency of the tested body enforce each other until the whole system gets excited. The electric signal becoming audible was transferred for evaluation from the amplifier to the input of the waveform analyser. Results were analysed by the above

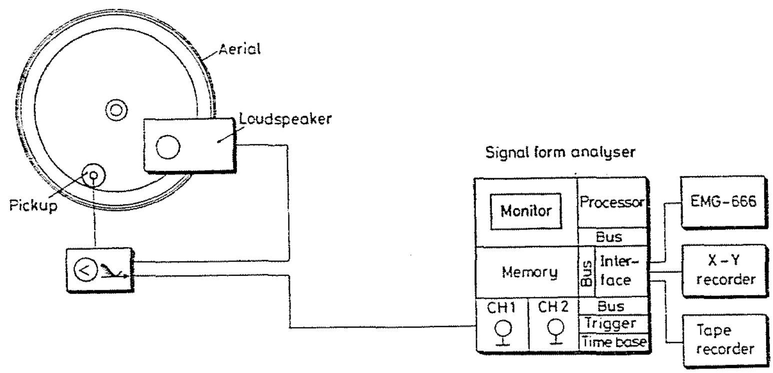

Fig. 4. Layout scheme of pickup test

described processing method. It should be noted that the weight of the pickup is negligible compared to that of the system thus it does not influence its vibration. Processing gave about 45 Hz for the dominant harmonic frequency and about 135 Hz for the next important harmonic.

Results of the two measurement methods showed beside the 15 Hz fundamental mode even the triple and sextuple harmonics to develop on the aerial.

The third measurement method (Fig. 5) was based on the technical possibility offered by the so-called quick-run camera. Two mirrors were fastened to the surface of the aerial and a further one to the standard of the primary emitter linked to the supporting tripod, in order to make motions of aerial and supporting structure distinguishable. Three independent laser sources were set up in a way that the beams reflected by the mirrors should strike a single square mesh target. A vibration cycle due to dynamic force effect caused the laser beam to describe an ellipse each on the target. For evaluation purposes the process was recorded by a 16 mm quick-run camera operated by a 1 kHz

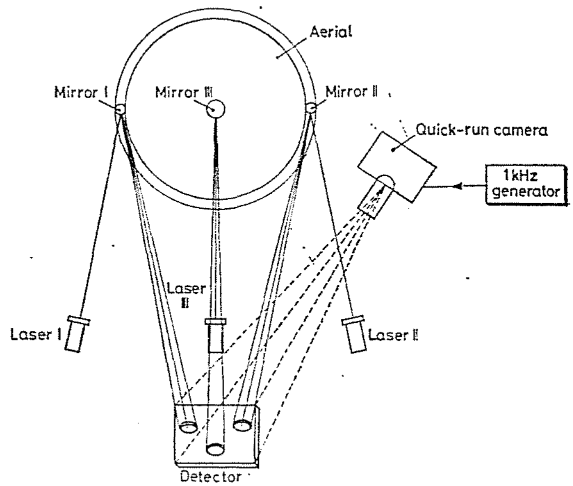

Fig. 5. Layout scheme for quick-run shooting

generator. On the mounting table the evaluation could even be frame by frame, but the process becomes well visible when slowed down to the desired rate by a normal projector. Advantage of this method is illustrativeness, at the disadvantage, however, of more difficult evaluation giving less exact results; information obtained with this measurement method, though in agreement with the former results, had a much lower quality content. Finally it should be noted that the three methods integrate each other, therefore it is expedient to use them together.

As a conclusion, adequate methods for the perception and evaluation of rapid dynamic motions of the parabolic aerial have been developed and realized. Irrespective of having been developed for a special problem, they are of general usefulness, namely they suit to test any rapid dynamic motion.

Summary

Three new measurement methods have been developed for determining and evaluating dynamic motions of bodies (e.g. a parabolic aerial).

First, a laser beam reflected by a mirror on the aerial containing in its direction the dynamic vibrations is received by an active detector. The information on the dynamic vibration is evaluated by a microprocessor signal form analyser. Second, the principle of positive feedback is used by means of vibration transformer pickup, an amplifier and a loudspeaker. The assembled system is excited at the resonance frequency of the parabole. Third, the information is visualized by means of a quick-run camera recording the laser beam containing information on the dynamic vibration.

Dr. Ervin FARKAS
Dr. Gyula GRACZKA } H-1521, Budapest