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THE PROBLEM OF DOCKING AND OPTICAL LOCATORS, (U)
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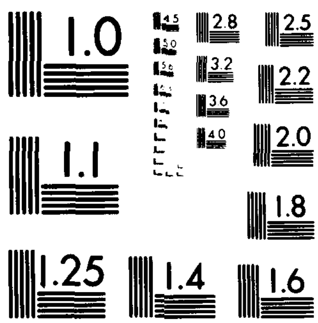

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FOREIGN TECHNOLOGY DIVISION

THE PROBLEM OF DOCKING AND OPTICAL LOCATORS

by

B. Fedorov

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EDITED TRANSLATION

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MICROFICHE NR: FTD-81-C-000302

6 THE PROBLEM OF DOCKING AND OPTICAL LOCATORS,

By: 10 B./Fedorov

~~English pages: 6~~

21 Edited trans. of [redacted] Aviatsiya i Kosmonavtika [redacted] (USSR) n2
[redacted] p41-44 1966, by

Country of origin: USSR
Translated by: Joseph E. Pearson.
Requester: FTD/TQTM
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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

Accession For		
NTIS GRA&I	☒	
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Unannounced	☐	
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The Problem of Docking and Optical Locators

by Lt. Colonel-Engineer B. Fedorov

The problem of spacecraft docking control in orbit has great significance for the development of cosmonautics. Docking is a necessary stage in the creation of orbital laboratories and scientific space stations in near-Earth and near-Moon space

It is not accidental, therefore, that space-flight programs already provide for the accomplishment of this important operation. Various technical devices are being developed for docking control.

The first designs of American spacecraft provided for the equipping of these spacecraft with optical locators, in which optical quantum generators (lasers) would be the radiation sources.

Optical locators of pulsed and continuous action, which make it possible to determine the direction, range and speed of spacecraft with high accuracy, can be employed to ensure docking. It is necessary to know these basic parameters for automatic, as well as manual docking.

Let us compare the optical locator and radar, both of which operate in the pulsed mode.

The data, presented in tables 1 and 2, show, that the optical locator in comparison with radar has greater accuracy in measuring the range and the angular coordinates of a target. The speed to a target and its angular accelerations are measured on the basis of the products of range and angle. The errors in the rate of variation of these parameters are proportional to the errors in the determination of these same parameters under the condition, that the noise will identically deteriorate the parameters of the optical locator, and of radar in the centimeter range.

1 Таблица 1

4 Параметры / 5 Тип локатора	8 Длительность импульса, сек.	9 Полоса усилителя, Мгц	10 Сигнал/шум	11 Задержка сигнала, сек.	12 Ошибка, м
6 Радиолокатор	10^{-6}	10	100	$2,3 \cdot 10^{-8}$	7
7 Оптический локатор	10^{-6}	100	100	$7 \cdot 10^{-9}$	2

2 Таблица 2

4 Параметры / 5 Тип локатора	14 Угловая расходимость луча, рад.	10 Сигнал/шум	13 Ошибка, рад.
6 Радиолокатор	$1,6 \cdot 10^{-2}$	100	$1 \cdot 10^{-4}$
7 Оптический локатор	10^{-4}	100	$4 \cdot 10^{-6}$

3 Таблица 3

4 Параметры / 5 Тип локатора	14 Коэффициент направленности антенны	15 Площадь антенны, см^2	16 Длина волны, см
6 Радиолокатор	10^7	$8 \cdot 10^5$	1.0
7 Оптический локатор	10^7	0.8	10^{-3}

Key: 1 - Table 1, 2 - Table 2, 3 - Table 3, 4 - parameters, 5 - type of locator, 6 - radar, 7 - optical locator, 8 - pulse duration, sec., 9 - amplifier band, MHz, 10 - signal/noise, 11 - signal delay, sec. 12 - error, m, 13 - error, rad., 14 - antenna directivity factor, 15 - antenna area, cm^2, 16 - wavelength, cm, 17 - angular divergence of the beam, rad.

The optical locator has one more significant advantage in comparison with radar. It is evident from table 3, that with one and the same locator directivity infra-red radiation with a wavelength of 10 μ makes it possible to reduce the dimensions of the receiving-and-transmitting device (due to the reduction in the dimensions of the antenna) by ten thousand times.

Let us examine the block diagram of an optical locator (fig. 1) for ensuring docking in orbit. It operates on the principle of of pulse measurement of range. Its radiation source is a gas optical quantum generator (laser) based on a helium-neon mixture. The excitation energy of the laser is supplied by a high-frequency master oscillator and a pulse modulator. The operating range of the locator is up to 10 km for a diffusely reflecting target and up to 100 km with the employment of mirror corner reflectors on board the spacecraft (cf. the magazine "Aviatsiya i Kosmonavtika", No. 9, 1965). Range is obtained in the following manner. The laser radiation is directed towards the spacecraft, equipped with mirror corner reflectors, which send the reflected radiation back to the laser. The energy reflected by the spacecraft is supplied to the receiving optical system, which directs it to the photoelectric receiver. Then the signal goes to the distance measuring unit, where the pedestal pulse is also supplied. The range is flashed on the display unit in the form of digital values. The design setup of the optical locator completely ensures automatic tracking of the spacecraft and the output of data about distance, speed, azimuth, angle of elevation and the corresponding angular velocities.

Another type of optical locator also exists for measuring distance in the case of the rendezvous of two spacecraft. The radiation source in it is a ruby laser, excited by a flash-discharge tube. At the output of the transmitting optical system is a partially reflecting mirror for creating a pedestal pulse. All the elements are located in the transmitting unit. Concentrated in the receiving unit are the receivin optics, interference filter, which separates the noise from the background, photomultiplier tube, the signal from which goes to the preamplifier and then to the display unit. The results of distance measurement are reproduced in digital form. The dimensions of the optical locator are small. Thus, for example, the model, created by the American firm "Martin", has a volume which does not exceed 30 dm^3 and its weight is 27 kg.

The press reports, that, at the present time, continuous-radiation locators are being developed. Gas or semiconductor optical generators are being employed for this purpose. A combined optical servo-system, which makes it possible to track a target and determine the range to it (fig. 2). In this case, the passive method is employed to determine the angular coordinates, and the active method is used to determine the range. The passive channel consists of an infra-red tracking head, operating on a source of radiation (a flash-discharge tube, a pulse photodiode), with the source installed on the objects, with which one plans to rendezvous in space. The infra-red head detects the object

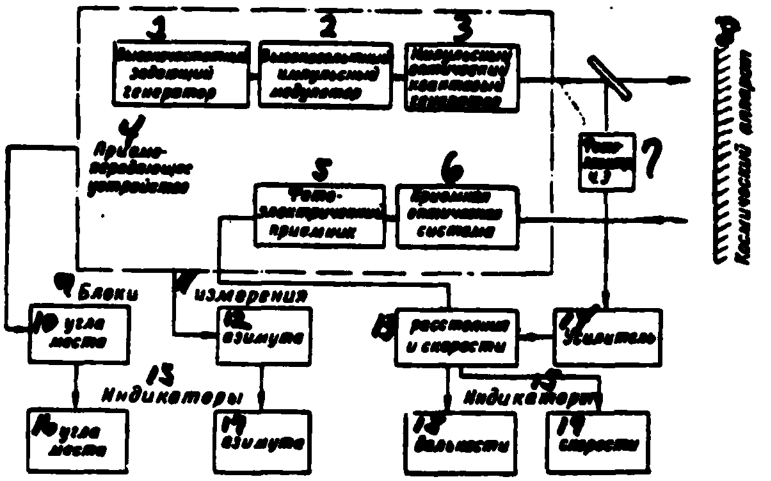

Рис. 1. [illegible]

Fig. 1. Block diagram of an optical tracking locator.
Key: 1 - high-frequency master oscillator; 2 - high-frequency pulse modulator; 3 - pulsed optical quantum generator (pulsed laser); 4 - receiving-and-transmitting device; 5 - photoelectric receiver; 6 - receiving optical system; 7 - photoelectric sensing element; 8 - spacecraft;; 9 & 11 - Measuring units; 10 - angle of elevation; 12 - azimuth; 13 - distance and speed; 14 - amplifier; 15 - displays- 16 - angle of elevation; 17 - azimuth; 18 - range; 19 - speed.

and transmits its coordinates to the tracking servo-drive and the decaders - scale-of-ten devices. This information is necessary for giuding the optical range finder to the object, where a continuous-radiation gas generator based on a helium-neon mixture serves as the radiation source. The radiation at the output of the optical generator is modulated with respect to amplitude. The radiation reflected by the spacecraft impinges on the optical receiving system, then on the radiation receiver, and then from it tothe phase detector, to which the signal from the modulation source is also supplied. The radiation reflected from the spacecraft is shifted in phase (the magnitude of the shift depends on the distance between the spacecraft). This distance is calculated from the phase shift. Both the pulsed and the phase locators are characterized by lower resolution with respect to speed than the locators, based on the employment of the Doppler effect. It is known,

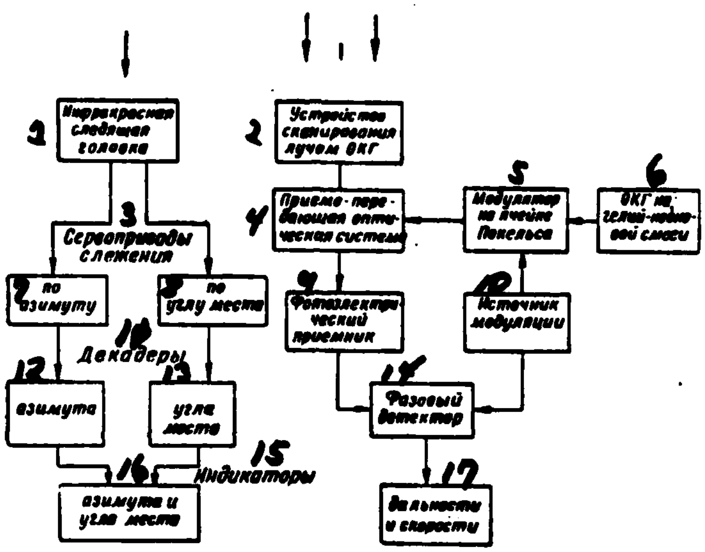

Рис. 2. Оптическая схема слежения за космическим аппаратом.

Fig. 2. Optical setup for the tracking of spacecraft.
Key: 1 - infra-red tracking head; 2 - laser beam scanning device; 3 - tracking servo-drive; 4 - optical receiving-and-transmitting system; 5 - modulator based on Pockels cell; 6 - helium-neon laser; 7 - by azimuth; 8 - by angle of elevation; 9 - photoelectric receiver: 10 - modulation source; 11 - decaders (scale-of-ten devices); 12 - azimuth: 13 - angle of elevation; 14 - phase detector; 15 - displays; 16 - azimuth and angle of elevation; 17 - range and speed.

that the effect consists in the variation in the frequencies of electromagnetic waves, perceived by an observer or a sensing element, due to the mutual motion of the radiation source and the receiver. Since the receiver and the radiation source are usually located next to each in the locator, and the frequency changes due to the mutual displacement of the locator and the spacecraft, which reflects radiation, the manifestation of the Doppler effect is doubled.

The Doppler optical locator (fig. 3) operates in the following manner. The radiation of the gas laser is directed at the spacecraft being docked, equipped with mirror corner reflectors. In this case part of the radiation is deflected to the immobile mirror installed on the first spacecraft. The radiation reflected by this mirror is directed to the photoelectric receiver, on which there also impinges the radiation, reflected by the mirror corner reflectors of the second spacecraft. If the spacecraft are both immobile relative to each other, then both beams, impinging on the receiver, have the same frequency.

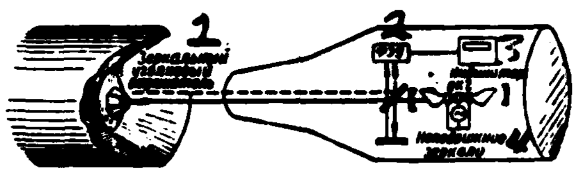

Рис. 3. Функциональная схема оптического доплеровского локатора.

Fig. 3. Functional diagram of a Doppler optical locator.
Key: 1 - mirror corner reflector; 2 - photomultiplier; 3 - display; 4 - immobile mirror; 5 - laser.

The mutual displacement of the spacecraft leads to a shift in the frequency of the oscillations of the reflected signal; the shift is -anifested in the form of pulsations of the signal taken from the radiation receiver. The frequency of the pulsations is proportional to the relative speed, and it can be readily used for indicating speed in the form of numerical values.

Specialists consider, that the use of lasers in the on-board location equipment is opening tempting prospects both from the point of view of a considerable improvement in the technical characteristics of locators (reduction in dimensions, decrease in weight), as well as from the point of view of a considerable increase in the accuracy of measuring range, direction and relative speed of spacecraft.