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(54) Benævnelse: **Fremgangsmåde og indretning til overføring af energi til et projektil**

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Method and Device for Transmitting Energy to a Projectile

DESCRIPTION

The invention concerns the problems of transmitting energy to a projectile during passage through the barrel and/or passage through the muzzle brake.

Such a transmission of energy is disclosed in US 7, 506, 586 B1. For programmable ammunition, energy must be provided to the projectile for the electronics integrated therein and for starting of the detonating train. For this purpose, various types of ammunition have small batteries that supply the requisite energy. Others are programmed and supplied with energy before firing. If the energy quantity is available continuously, for example during storage or the process of loading in the weapon, undesired explosion of the projectile may occur in the event of a malfunction in the electronics. For this reason, the use of simple energy storage devices such as a battery is not always appropriate.

It is thus recommended for safety reasons to provide the energy to the projectile in close temporal proximity to firing, for example after the ignition of a propellant charge and before leaving the muzzle opening of a gun barrel. This ensures that the round of ammunition cannot detonate itself before firing, as it has no energy required for this purpose.

The battery from DE 31 50 172 A is not activated until after the gun of the gun barrel has left, which is accomplished by means that include a mechanical timer. The battery in DE 199 41 301 A also is first activated by high accelerations during firing.

According to DE 488 866 A, a capacitor of the detonator is charged via external contacts in the firing position. According to the teaching in DE 10 2007 007 404 A, an ignition capacitor is charged as early as following the end of muzzle safety, which is to say approximately two seconds before the end of the flight time. The ignition capacitor according to DE 26 53 241 A is charged inductively via magnet coils before firing.

US 4,144,815 A describes a type of energy transmission device in which the gun barrel serves as a microwave guide, so that the energy and the data are transmitted prior to firing. A receiving antenna on the detonator receives the radiated signal and directs it through a changeover switch to either a rectifier device or a filter acting as a demodulator that filters the data out of the incoming signal. The rectifier device in this design serves to produce a supply voltage, which is then stored, from the incoming signal.

In DE 31 50 172 A, the supply voltage is provided inductively before or during loading of the projectile.

Also known are devices that obtain the energy from the kinetic energy of the projectile. Here, a mechanism is built into the projectile that converts the required energy from the acceleration following ignition of the propellant charge into electromagnetic energy, and in so doing charges a storage device located in the projectile.

Thus, CH 586 384 A describes a method in which a soft iron ring and a ring-shaped permanent magnet are displaced in the direction of the projectile axis relative to an induction coil as a result of the linear projectile acceleration, by which means a voltage that charges a capacitor is generated in the coil. For the sake of safety, this unit is then provided in CH 586 889 A with a transport safety device that is destroyed only by the, or a, high acceleration during firing.

It can be a disadvantage here that the acceleration of the projectile in the gun barrel is used, since this cannot be controlled with exact precision. This causes the energy charges to vary, so that the projectile is given too much or even too little energy in its travel. Too little energy then has the disadvantage that functionality is not guaranteed. A further disadvantage is the complex and thus space-consuming conversion mechanism for converting mechanical energy into electromagnetic energy. Moreover, with the extreme environmental influences (shocks during firing, transverse accelerations, and spin) on the projectile during firing, this mechanism can be destroyed. In order to preclude this, design measures are necessary that not only make the round of ammunition costlier, but also require additional space in the projectile and make it heavier.

Generators in the projectile head are proposed in DE 25 18 266 A and DE 103 41 713 A. An alternative to these is the use of piezo crystals, as proposed and implemented in DE 77 02 073 A, DE 25 39 541 A or DE 28 47 548 A.

In this context, the latter proposals already take the route of replacing prior art energy conversion mechanisms with an energy transmission system that for its part impresses the necessary energy on the projectile no later than during passage through the muzzle opening.

The object of the invention is to create a system that allows for optimal energy transmission with simple construction.

The object is attained through the features of claim 1 and claim 7. Advantageous embodiments are shown in the dependent claims.

The invention is based on the idea of carrying out the energy transmission inductively and/or capacitively. It is proposed to use a waveguide for the energy transmission, since the electromagnetic field in a waveguide is concentrated. The energy transmission system used here consists at least of a waveguide and a transmitting coupler for the energy transmission that is supplied by a signal generator. In contrast, the projectile has at least one sensor that receives the signal and charges a storage device in the projectile. The waveguide for the energy transmission can be the gun barrel, the muzzle brake, or an additional part between the end of the gun barrel and the start of the muzzle brake, or can also be attached to the end of the muzzle brake. Incorporation in the region of the opening between a muzzle brake and a gun barrel has proven to be preferred when a programming of the projectile or shell is provided, for example.

The signal generator (e.g., oscillator) supplies a signal with a constant center frequency that lies below the lowest cutoff frequency of the waveguide. As a function of the geometry and type of the transmitting coupler (coil, dipole, etc.), multiple waveguide modes (TE_{mn} where m = 0, 1, 2, … and n = 1, 2, 3, …) are excited. The signal generator generates either a carrier in continuous-wave operation (CW operation) or a modulated signal.

The utilization of a waveguide below the cutoff frequency to measure the muzzle velocity of a projectile or the like is already known from DE 10 2006 058 375 A. This document proposes using the gun barrel or launcher tube and/or parts of the muzzle brake as a waveguide (a tube with a characteristic cross-sectional shape that has a wall with very good electrical conductivity is considered a waveguide. Primarily square and round waveguides are widely used as a technology), which, however, is operated below the cutoff frequency of the applicable waveguide mode. However, a utilization as energy transmission system is not addressed.

In a further development of the invention, provision is made to additionally use the waveguide for the V_0 measurement and not for the energy transmission alone. The muzzle velocity itself preferably can be measured or determined before and/or after the projectile. In the case of measurement before the projectile, the fact is taken into account that the tip of the projectile influences the electromagnetic field when passing through the waveguide. In the case of measurement after the projectile, the essentially flat or planar surface of the base is exploited, by which means the measurement takes place independently of the shape of the tip of the projectile. In this process, the base influences the electromagnetic field. In each case, this change is sensed by a receiving coupler in the waveguide and supplied to an analysis device. Such a method is known from WO 2009/141055 A1. The distance between a transmitting coupler, which for its part receives the signals from the oscillator, and the receiving coupler is variable and can be chosen individually as a function of the mode selection of the waveguide, but depends on the caliber, the interior dimensions of the waveguide, and the frequency.

Furthermore, the energy transmission can be combined with a programming of the projectile, which itself is the subject matter of a parallel patent application. For programmable rounds of ammunition, information must be communicated to the projectile concerning its detonation time and/or flight path. The signal with the frequency for the programming is also below the cutoff frequency of the applicable waveguide mode here. So that the programming is independent of the magnitude of the muzzle velocity V_0, the frequency should also be >0 Hz here. This has the result that the V_0 of slow projectiles as well as fast projectiles has no effect on the programming. The carrier of the frequency is modulated with the appropriate information for the projectile, and the modulated signal is then provided to the transmitting coupler in the waveguide. The transmitting coupler now excites the corresponding electromagnetic field in the waveguide. When the projectile passes through the waveguide, the projectile receives the signal in a contactless manner with capacitive and/or inductive coupling by means of a receiving coupler located in the projectile. It is a matter of course that the device for the energy transmission is to be incorporated ahead of the device for programming, and that the spacing of the two is to be chosen such that the programming can also proceed successfully.

The invention shall be explained in detail using an exemplary embodiment with drawings. The drawings show, in schematic representation:

Fig. 1 an energy transmission system,

Fig. 2 the energy transmission system in a combination with a V_0 measurement,

Fig. 3 a process chart for illustrating the sequence of energy transmission and / or V_0 measurement,

Fig. 4 a further development with projectile programming.

Fig. 1 shows an energy transmission system 1, here incorporated between an end 2' of a gun barrel 2 and a muzzle brake 3 (not a necessary condition). The energy transmission system 1 consists of at least one waveguide 4 (and / or waveguide segments), and at least of a transmitting coupler 5 that is supplied with a frequency f_2 by an oscillator 6. The reference number 7 identifies a projectile to which energy is to be transmitted during passage through the energy transmission system 1. The waveguide 4 in this design can be the attachment 3' of the muzzle brake 3 or a constituent part of the gun barrel end 2. In this example, the waveguide 4 is a separate part that is incorporated between the gun barrel 2 and the muzzle brake 3.

Fig. 2 shows the energy transmission system 1 from Fig. 1 in combination with a V_0 measurement. In the preferred embodiment, the same transmitting coupler 5 is used for the V_0 measurement. The reference number 10 indicates a receiving coupler in the waveguide 4 that is required for the V_0 measurement and that is electrically connected to an analysis device 11. An additional oscillator 12 supplies an additional signal with a frequency f_1 for the V_0 measurement.

The mode of operation or the method is now explained in general with reference to the preferred embodiment from Fig. 2, which is to say in a possible combination of V_0 measurement and energy transmission:

The signal with the frequency f_1 is provided for the V_0 measurement, and the signal with the frequency f_2 is provided for the energy transmission. Both frequencies f_1 and f_2 are below the cutoff frequency of the relevant waveguide mode, and thus are lower than the cutoff frequency. In addition, it can be the case that $f_1 \neq f_2$ or $f_1 = f_2$.

The frequencies f_1 and f_2 preferably are optimized for both the V_0 measurement and energy transmission when the frequency used for both the measurement and the energy transmission (the same $f_1 = f_2$) is already optimal. So that both the measurement and the energy transmission are independent of the magnitude of V_0, the frequencies should be >0 Hz. This has the effect that the V_0 of slow projectiles as well as fast projectiles is always measured with the same precision, which is also true with respect to the energy transmission.

When the projectile 7 passes through the waveguide 4, the muzzle velocity V_0 can be measured in a known manner before and/or after the transmission of energy. For the energy transmission, the projectile 7 has a sensor 8 that receives the signal with the frequency f_2 and charges a store 9 in the projectile 7. As it flies through, the projectile 7 receives the requisite quantity of energy so that the store 9 is charged after leaving the waveguide 4.

Fig. 3 shows an overview of the sequence of the energy transmission, also in combination with the V_0 measurement. If no V_0 measurement is provided, only the path “energy transmission” is chosen. In contrast, if the intent is for both the measurement and the energy transmission to take place using the same waveguide, then four different alternative methods are available in principle: first the V_0 measurement followed by the energy transmission, or first the energy transmission followed by the measurement, or the energy transmission included in respectively one V_0 measurements’, or a parallel V_0 measurement and energy transmission. If the number of components/waveguides permits, the steps with the energy transmission or V_0 measurement can be performed multiple times until the shell or projectile 7 exits the waveguide 4 and subsequently passes through the muzzle brake, for example.

Fig. 4 shows augmentation with a programming device 20. In this case, said programming device can likewise use the transmitting coupler 5 that is already present for the V_0

measurement and/or energy transmission for the programming. Preferably, an additional signal generator 13 produces the carrier signal f_3 for the programming. The information for the shell or projectile is then modulated 14 onto said carrier signal and is impressed on or transmitted to a receiving coupler 16 contained in the projectile 7 via the transmitting coupler 5 or via an additional transmitting coupler 15. An additional receiving unit 17, which is electrically connected to a receiving coupler 18 in the waveguide region 4, can serve to provide a test signal for the correct programming.

PATENTKRAV

1. Fremgangsmåde til energioverføring til et projektil (7) under passagen gennem et våbenløb (2), mundingsbremse (3) eller lignende ved hjælp af et energioverføringssystem (1), hvor

- projektilet (7) ved passagen præges med en frekvens (f_2), der er genereret til energioverføringen af en signalgenerator (6), hvorved dette lades med energi, og hvor
- prægningen sker inden for passagen med en bølgeleder (4), der drives under grænsefrekvensen af den pågældende bølgeledermodus (TE, TM).

2. Fremgangsmåde ifølge krav 1, **kendetegnet ved, at** der i bølgelederen (4) kan foretages en V_0-måling af projektilet (7) ved hjælp af en til målingen genereret frekvens (f_1).

3. Fremgangsmåde ifølge krav 2, **kendetegnet ved, at** det tilsvarende elektromagnetiske felt i bølgelederen (4) stimuleres, således at frekvensen (f_1) kan reflekteres ved projektilet (7) og evalueres.

4. Fremgangsmåde ifølge et af kravene 1 til 3, **kendetegnet ved, at** en programmering af projektilet (7) kan foretages i bølgelederen (4) ved hjælp af information, der er genereret til programmeringen og moduleret til denne bærerfrekvens (f_3), og overføres til dette.

5. Fremgangsmåde ifølge krav 4, **kendetegnet ved, at** bæreren af frekvensen til programmeringen moduleres med den tilsvarende information til projektilet (7), og det modulerede signal overføres berøringsløst til projektilet (7) ved hjælp af kapacitiv og/eller induktiv kobling.

6. Fremgangsmåde ifølge et af kravene 1 til 5, **kendetegnet ved, at** frekvenserne er > 0Hz.

7. Våbenløb (2) og/eller mundingsbremse (3) med en indretning til energioverføring til et projektil (7) under passagen gennem våbenløbet (2) og/eller mundingsbremsen (3) ved hjælp af et energioverføringssystem (1), hvor energioverføringssystemet (1) består af

- en bølgeleder (4), der drives under en grænsefrekvens af den pågældende bølgeledermodus (TE, TM),
- en sendekoblingsindretning (5), der ved projektilets (7) passage via en sensor (8) præger dette med en frekvens (f_2), der til energioverføringen er genereret af en signalgenerator (6), hvorved et i projektilet (7) integreret lager (9) lades med energi.

8. Våbenløb (2) og/eller mundingsbremse (3) ifølge krav 7, **kendetegnet ved, at** der til måling af en V_0-mundingshastighed af projektilet (7) i bølgelederen (4) er integreret en sendekoblingsindretning (5) og mindst en modtagekoblingsindretning (10), hvorved eksempelvis en yderligere signalgenerator (12) er forbundet med sendekoblingsindretningen (5).

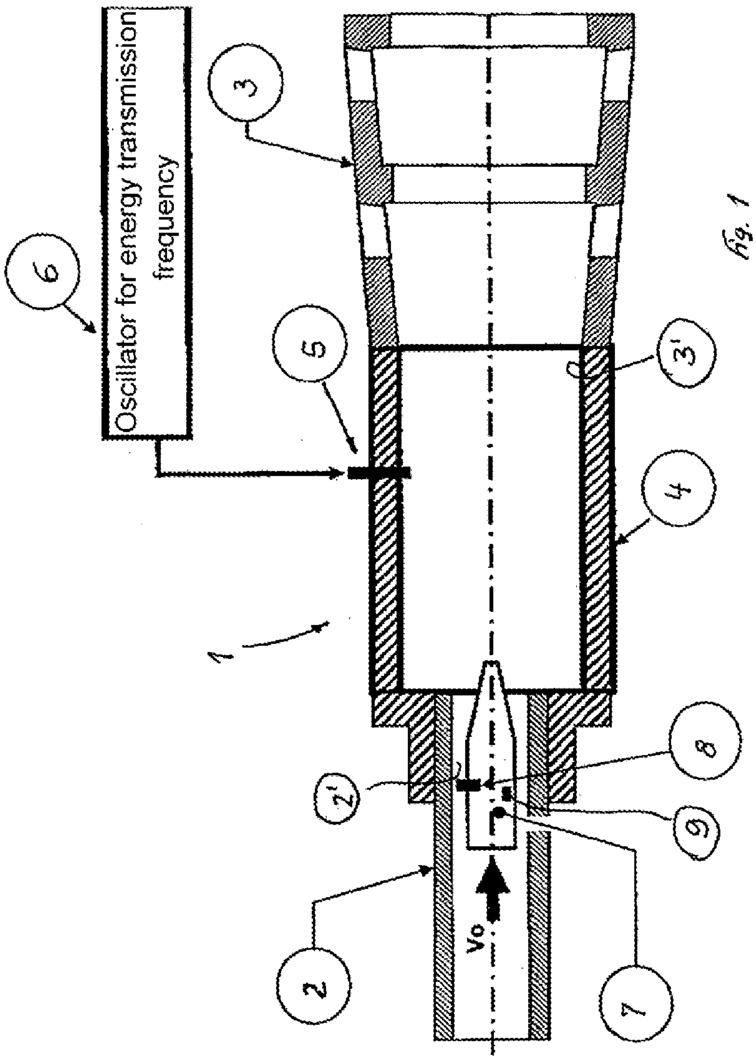
9. Våbenløb (2) og/eller mundingsbremse (3) ifølge krav 8, **kendetegnet ved, at** den af energioverføringen anvendte sendekoblingsindretning fungerer som sendekoblingsindretning (5).

10. Våbenløb (2) og/eller mundingsbremse (3) ifølge et af kravene 7 til 9, **kendetegnet ved, at** der til programmering af projektilet (7) er integreret en signalgenerator (13), der signalteknisk er forbundet med sendekoblingsindretningen (5) eller en yderligere sendekoblingsindretning (15) via en modulationsenhed (14), hvor projektilet (7) omfatter en yderligere modtagekoblingsindretning (16).

11. Våben (2) og mundingsbremse (3) ifølge et af kravene 7 til 10, **kendetegnet ved, at** energioverføringssystemet (1) er integreret mellem en ende (2') af våbenløbet (2) og mundingsbremsen (3).

12. Våbenløb (2) og mundingsbremse (3) ifølge krav 11, **kendetegnet ved, at** bølgele-

deren (4) kan være vedhæftningen (3’) af mundingsbremsen (3) eller en bestanddel af våbenløbsenden (2).


Oscillator for energy transmission frequency
1
2
2'
3
3'
4
5
6
7
8
9
Vo
fig. 1

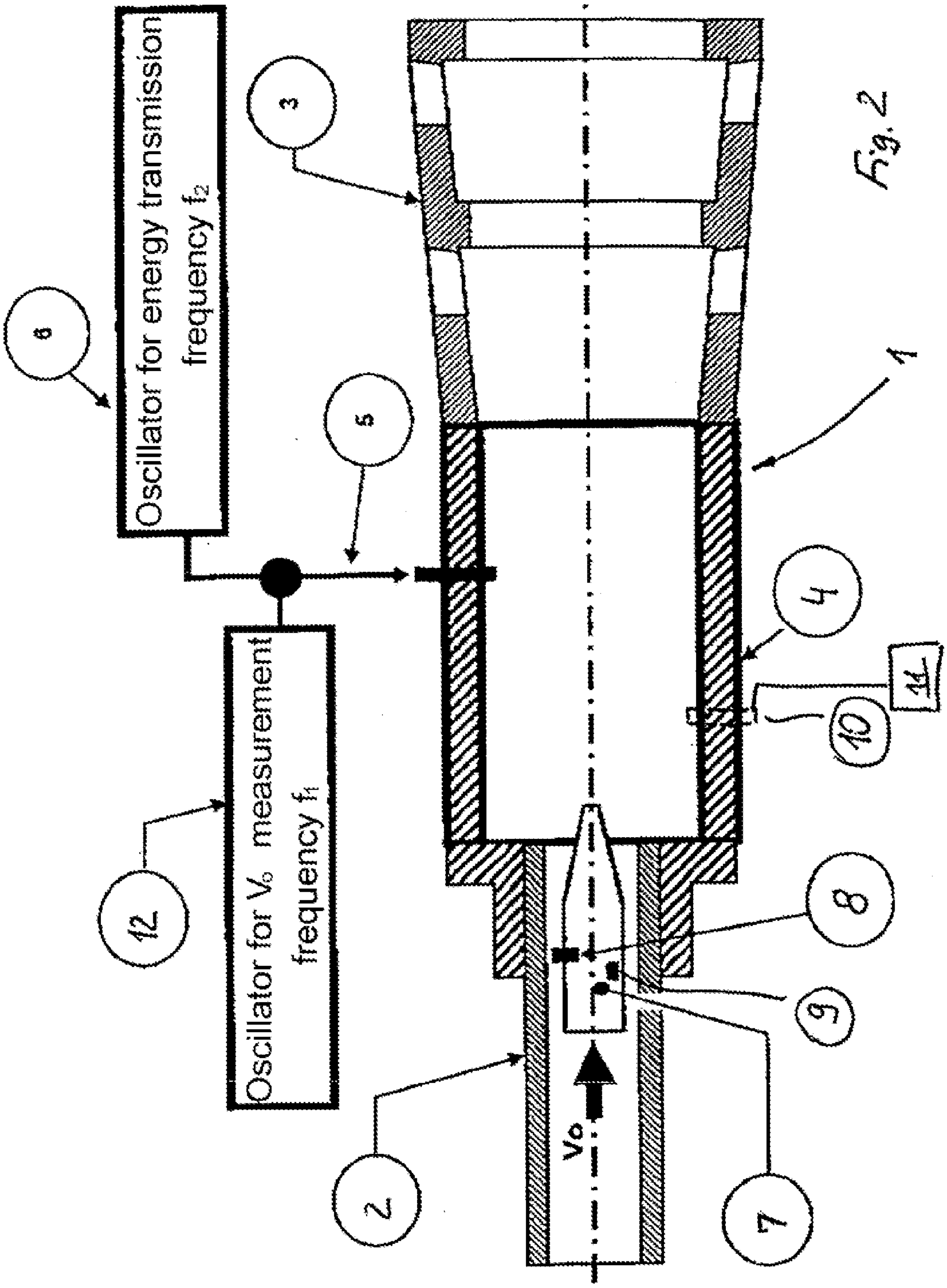

Oscillator for energy transmission frequency f_2
6
5
3
1
4
10
11
Oscillator for V_o measurement frequency f_1
12
8
9
Vo
2
7

Fig. 2

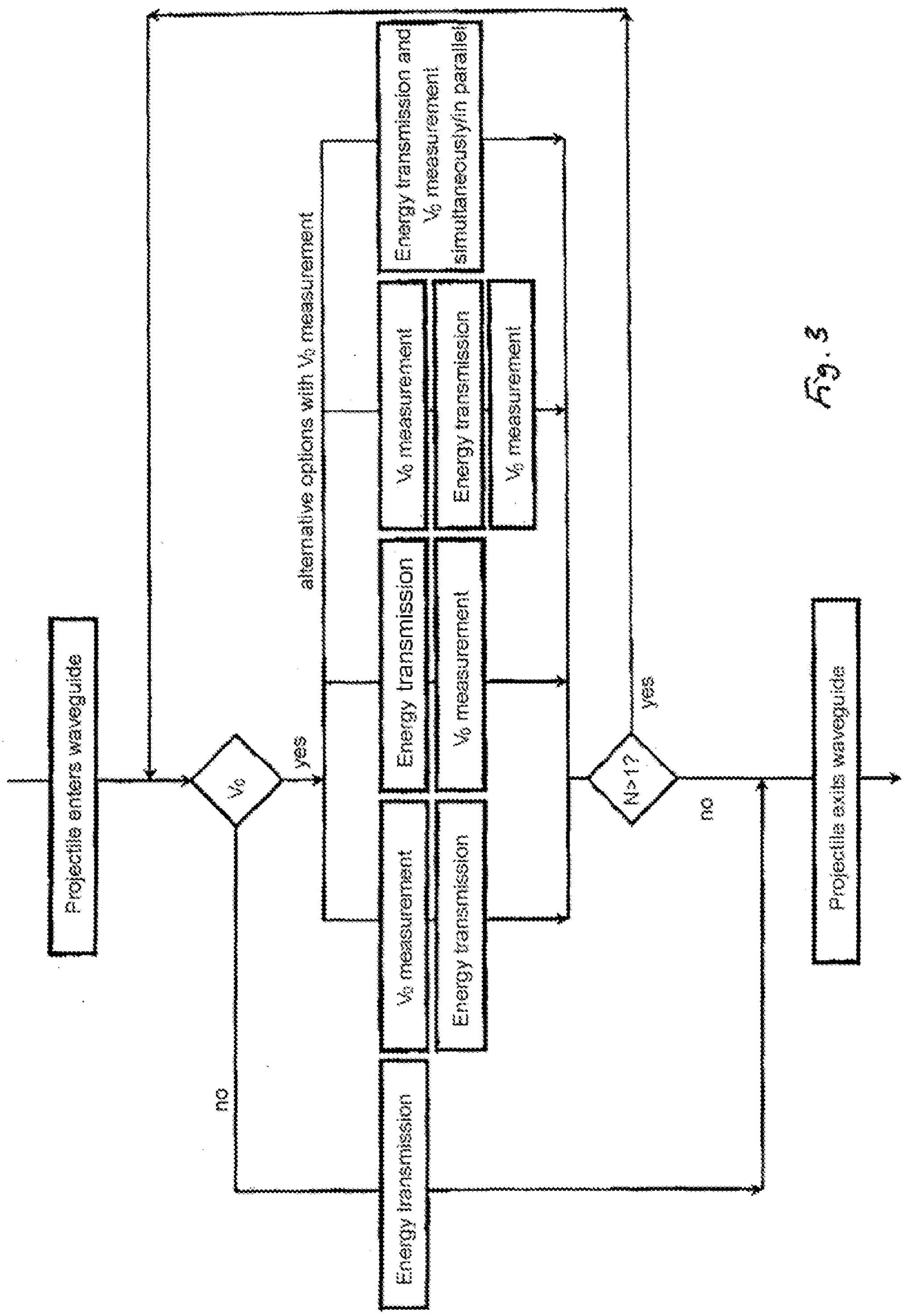

Projectile enters waveguide
V_0
yes
no
alternative options with V_0 measurement
V_0 measurement
Energy transmission
Energy transmission
V_0 measurement
V_0 measurement
Energy transmission
V_0 measurement
Energy transmission and V_0 measurement simultaneously/in parallel
Energy transmission
N>1?
yes
no
Projectile exits waveguide

Fig. 3

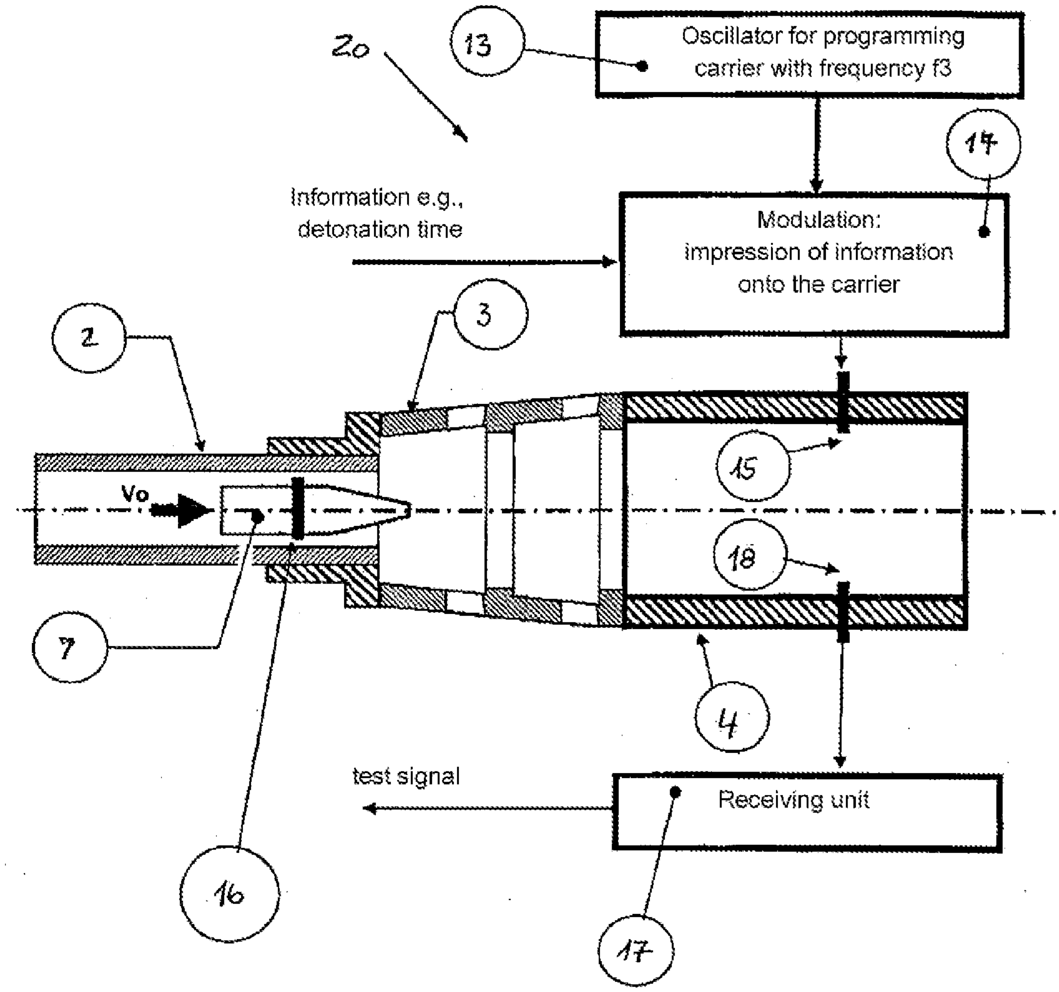

20
13
Oscillator for programming
carrier with frequency f3
14
Information e.g.,
detonation time
Modulation:
impression of information
onto the carrier
3
2
Vo
15
18
7
4
test signal
Receiving unit
16
17

Fig. 4