OPIC
Office de la propriété intellectuelle du Canada

CIPO
Canadian Intellectual Property Office

(12) (19) (CA) **Demande-Application**

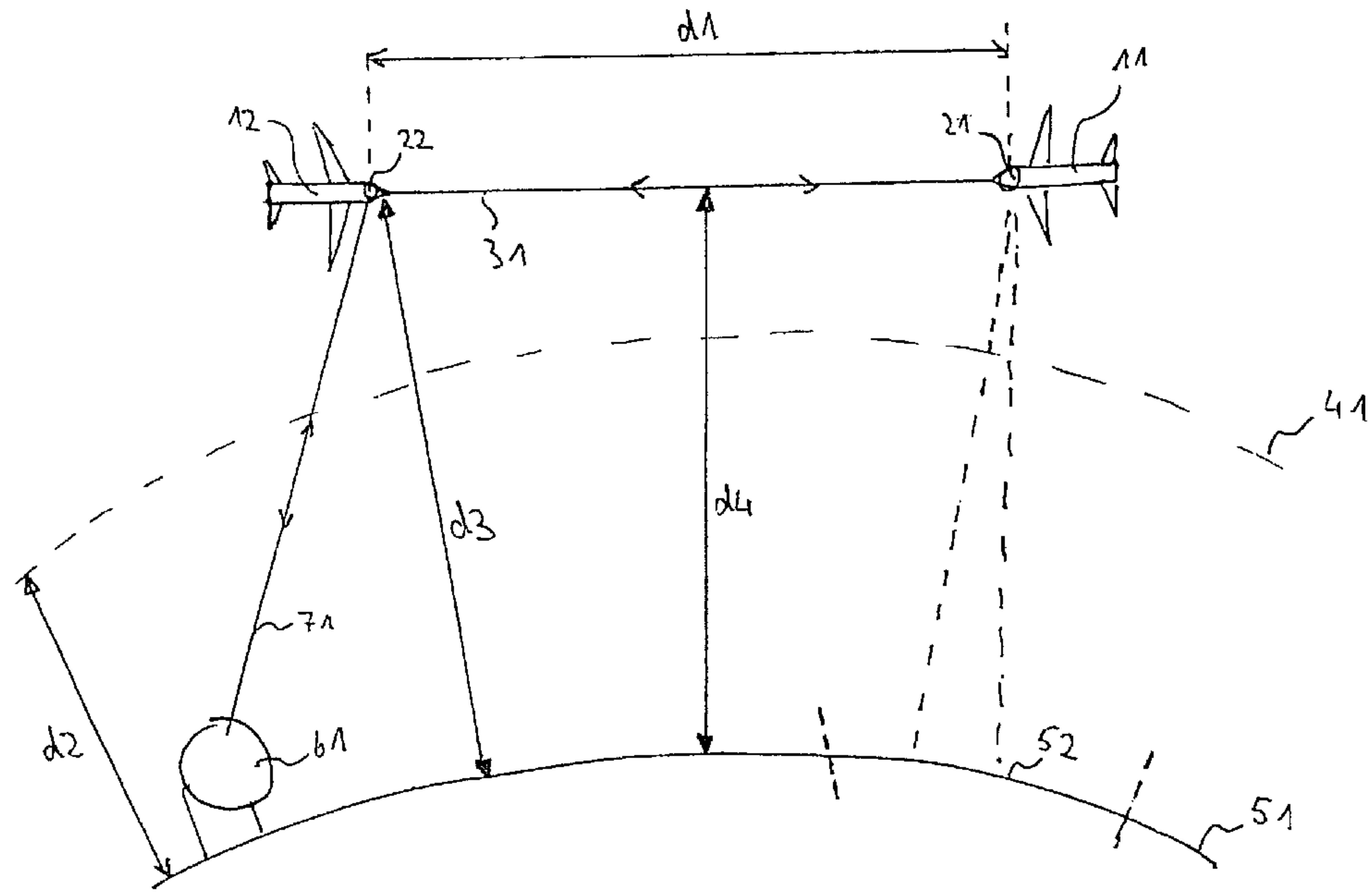
(21) (A1) **2,307,382**
(22) 2000/05/01
(43) 2000/12/03

(72) PRIBIL, KLAUS, CH
(71) CONTRAVES SPACE AG, CH

(51) Int.Cl.[7] H04B 10/10
(30) 1999/06/03 (1999 01041/99) CH

(54) **RESEAU DE TRANSMISSION DE DONNEES SANS FIL ET METHODE D'EXPLOITATION DU RESEAU DE TRANSMISSION DE DONNEES**

(54) **WIRELESS DATA COMMUNICATIONS NETWORK AND METHOD FOR OPERATING THE DATA COMMUNICATIONS NETWORK**



(57) The present invention relates to a data communications network and a method for operating the data communications network, wherein the data communications network essentially consists of fixed stations on or near the ground and freely movable flying objects, which are linked together by means of wireless data links. The concept of the invention is based on interruption-free optical laser communications between various flying objects, which typically operate above the cloud tops. These laser-optical data links offer the greatest degree of interception security, and in addition can be advantageously built up or changed very rapidly. Since the individual flying objects operate independently of each other over a wide range, a maximal autonomy of the communications network can be assured. In particular is it possible by means of this to reconfigure the data communications network very rapidly and to adapt it in this way to changed conditions. Moreover, redundancy, and therefore greater flexibility in the topology of the data communications network, can be created by the use of additional flying objects.

ABSTRACT OF THE DISCLOSURE

Data Communications Network and Method for Operating the Data Communications Network

The present invention relates to a data communications network and a method for operating the data communications network, wherein the data communications network essentially consists of fixed stations on or near the ground and freely movable flying objects, which are linked together by means of wireless data links. The concept of the invention is based on interruption-free optical laser communications between various flying objects, which typically operate above the cloud tops. These laser-optical data links offer the greatest degree of interception security, and in addition can be advantageously built up or changed very rapidly.

Since the individual flying objects operate independently of each other over a wide range, a maximal autonomy of the communications network can be assured. In particular is it possible by means of this to reconfigure the data communications network very rapidly and to adapt it in this way to changed conditions. Moreover, redundancy, and therefore greater flexibility in the topology of the data communications network, can be created by the use of additional flying objects.

Wireless Data Communications Network and Method for Operating the Data Communications Network

FIELD OF THE INVENTION

The invention relates to a wireless data communications network in accordance with the preamble of claim **1**, and a method for operating the data communications network in accordance with the preamble of claim **9**.

BACKGROUND OF THE INVENTION

It is known in connection with wireless data communications networks to transmit the data to be transmitted without the interposition of a conducting medium, for example an electrical conductor or a glass fiber. Here, the data to be transmitted are forwarded by means of suitably modulated electromagnetic or optical waves.

Data transmission methods by means of high-frequency electromagnetic waves are known in a number of variations and are presently employed in telecommunications in particular. For example, telephone calls from the fixed network or mobile radio network can be transmitted extra-terrestrially over short to medium ranges. Further than that, this data transmission method has been successfully used for over **20** years for transmitting information from satellites over long distances. At present, satellite transmissions are in particular used for the transmission of radio and broadcast frequencies, but also for intercontinental telephone transmissions.

Wireless optical data transmission methods are operated by means of data-modulated laser pulses. In comparison with high- frequency radio link connections, the optical free space connections have been shown to be very advantageous for data transmissions for various reasons. For example, because of its extremely short wavelength, an optical laser beam can be very easily radiated by means of a relatively small optical transmission device and therefore at a very small spatial angle. In contrast to the above mentioned radio link connections, it is possible because of this good focusing ability of the laser beam to employ very small transmitting stations and receiving antennas in the course of optical data transmissions. With these minimalized optical antennas considerably larger data rates can be transmitted at a minimal transmitting output than it would be possible, for example, with data transmissions by means of radio link systems at the same transmitting output. Moreover, optical data transmission methods advantageously have almost no background signal noise.

The good focusing ability, or respectively capability for bundling, of the optical transmission beam, however, requires an extremely precise determination of the direction of the transmitted beam in the transmitting station, as well as exact tracking and alignment of the optical receiver device in the receiving station. Moreover, the problem arises in optical free space data communications in particular, that at least one of these stations is arranged freely movable in space, which makes leading the optical laser beam in respect to the optical receiver device necessary. A method and an arrangement for the disruption- free operation of optical data links between satellites, wherein a laser beam is employed for the data transmission between the respective satellites, is described in **EP 0 876 013 A1**.

Besides a high data transmission rate, the lowest possible energy use of the transmitting/receiving stations, and a data transmission as free as possible of signal noise, additional requirements are being made on data communications networks in accordance with the species, in particular by military air and space technologies.

For military reconnaissance, or respectively information transmission in crisis or war zones, the data communications network employed there must assure the highest degree of freedom from interception and interference with the data transmissions. Although as a rule an existing communications network is present in such crisis or war zones, it is not to be used, especially for reasons of a deficient or lacking interception security. Up to now a satellite-supported data communications system had therefore been used as an obvious solution, wherein the data to be transmitted are sent from a ground-supported or aircraft-supported transmitting station via satellites to the receiving station. In this case data transmission occurs via radio signals. However, it was shown that this data transmission system is not one hundred percent secure from being intercepted, and that moreover it can be interfered with, or respectively disrupted, by third parties in an undesirable manner.

It is furthermore of decisive importance that an interception-free communications network can be established very quickly and with simple means. This communications network should be operable nearly independently of the existing infrastructure. Moreover, a change in the situation can for example make it necessary to change the structure of the data communications network, which makes a certain degree of flexibility of the network topology used desirable.

Such a data communications network meeting the requirements mentioned could not be satisfactorily realized up to now.

Based on this, the object of the present invention is to make available a universally usable data communications network which is secure against interception and interruption to the highest possible degree, which moreover is suitable for data transmissions at a high information density. Furthermore, it is intended to make available a method for operating this data communications network.

The object in regard to the arrangement is attained in accordance with the invention by means of a data communications network having the characteristics of claim **1**.

In accordance with this, a wireless data communications network is provided, wherein a plurality of flying objects capable of changing their positions are located in a common, limited area in the earth's atmosphere or at the distance of the earth atmosphere from the surface of the earth, can be connected with each other by means of an optical transceiver station in each flying object, each of which can be connected interference-free by means of first wireless data links which are designed at least partially as laser-optical data links, and by the network having at least one fixed station on or near the ground, which can be connected with at least one transceiver station via second wireless links.

The object in regard to the method is attained by a method for operating a data communications network having the characteristics of claim **9**.

In accordance with this, a method for operating a data communications net is provided, which includes the following method steps:

(a) a data transfer is performed between at least two transceiver stations, each provided in flying objects, via the first data links, wherein an optical laser signal is used at least in sections for the data transfer,

(b) then a wireless data transfer between at least one transceiver station and a station on near the ground takes place via the second data links, wherein a data signal is received from the respective transceiver station and/or is transmitted to the respective transceiver station.

The dependent claims are directed to preferred embodiments and further developments of the invention.

The present invention describes an optical data communications network, which is based on fixed stations on or near the ground, and non-stationary flying objects, which are connected with each other via wireless data links and therefore constitute a communications network which is freely configurable over a wide range. This data communications network meets the demands mentioned at the outset, which are made on data communications particularly in crisis or war zones, and permits a linkage of the input and output signals of the data communications network which is free of electrical feedback.

The proposed concept is essentially based on interruption- free optical laser communications between different flying objects operating above the cloud tops. These laser-optical data links offer the greatest amount of interception security, and can furthermore be advantageously established, or changed very rapidly. This data communications network, which is a competitor of satellite-supported communications networks, can, in contrast to the latter, be installed with comparatively simple and cost-effective means. Only at least two flying objects are required for the build-up of such a data communications network, besides the stations on or near the ground. Since the individual flying objects, each of which represents the network linkages of the data communications network, can operate independently of the other within wide limits, a maximal autonomy of the network linkages can be assured. In particular, by means of this the data communications network can be very rapidly reconfigured and adapted to changes in this way. By employing additional flying objects it is also possible to generate redundancy, and therefore greater flexibility in the topology of the data communications network.

Further details and advantages of the invention will be explained in what follows by means of two exemplary embodiments. The invention will be explained in greater detail in what follows by means of the exemplary embodiments represented in the drawings. Shown are here in:

Fig. 1, a first exemplary embodiment of a data communications network in accordance with the invention,

Fig. 2, a second exemplary embodiment of a data communications network in accordance with the invention,

Fig. 3, a diagram indicating the maximum track distances as a function of the cloud tops and the flight level of the aircraft.

Equal or functionally equal elements are provided with the same reference numerals in all drawing figures.

Fig. 1 represents a first data communications system in accordance with the invention, which is built up by means of aircraft. Two aircraft flying at high altitude are identified by **11**, **12** in **Fig. 1**. Optical receiver stations **21**, **22** have been installed in each aircraft **11**, **12**. The transceiver stations **21**, **22** are directly coupled with each other by means of an optical data link **31**. Furthermore, a base station **61**, which is arranged on the surface **51** of the earth, is provided which, in the present case, is connected via a further data link **71** with an aircraft **11**.

An interruption-free optical data link **31** is essential for this coupling of the transceiver stations **21**, **22**. For this reason, the two aircraft **11**, **12** and the data link **31** connecting them, have been arranged above the cloud tops in the present example. Here, the flight level of the aircraft was identified as **d3**, the distance of the aircraft from each other as **d1**, and the cloud tops as **d2**.

The transceiver stations **21**, **22** can be designed for bidirectional or unidirectional data transfer, i.e. for transmitting and/or receiving optically modulated data, wherein the data to be transmitted are modulated in the form of a broadband laser beam. The optical transmitting unit of a transceiver station **21**, **22** designed for transmitting contains means for the optical transmission of the data, a laser unit and an optical output amplifier. As a rule, an optical receiving unit of a transceiver station **21**, **22** designed for receiving has a reception amplifier and means for optical data transfer. Furthermore, the transceiver stations **21**, **22** have means for position stabilization, as well as means for tracking the optical beam. By means of this it is possible to assure that an interruption-free data link **31** is assured in case of slight vibrations, or respectively relative movements of the transceiver stations **21**, **22** in respect to each other. The optical transmitting and receiving devices of a transceiver station **21**, **22** are advantageously arranged so they are freely pivotable in space, so that they can build up interruption-free data links with other, also freely movable transceiver stations **21**, **22**.

The structure and functioning of such transceiver stations is exactly described in **EP 0 847 150 A1** and **EP 0 863 627 A1**. The full contents of these patent applications are hereby included in the subject of the present patent application ("incorporated by reference").

The functioning of the data communications network from **Fig. 1** will be briefly described in what follows.

The first aircraft **11** in the example shown is located above a partial area **52** of the surface of the earth, while the second aircraft **12** is located above an area far distant from the partial area **52**. The partial area **52** can be, for example, a crisis or war zone, above which the first aircraft **11** flies for the purpose of aerial reconnaissance. The data obtained from this aerial reconnaissance are transmitted from the first transceiver station **21** to the second transceiver station **22** in the second aircraft **12** via a broadband data-modulated laser beam. It is advantageously possible to transmit data at transmission rates far above **100** Mbit/sec by means of this broadband laser beam. The data-modulated laser beams have a minimal angle of dispersion and prevent therefore an undesired radiation. It is possible to assure by means of this type of data transmission that an interception-secure and interference-secure data transmission takes place at least above the partial area **52**.

The demodulated data can be transmitted from the second aircraft **12** via a further data link **71** to the station **61** on or near the ground. The data transmission via the second data link **71** can take place by means of radio signals, since in the case shown the ground station is located far outside the partial area **52**, so that here a reduced requirement for interference, or respectively interception security of the data transmission results. However, an optical data transmission between the aircraft **12** and the station **61** on or near the ground would be conceivable.

Fig. 2 shows a second exemplary embodiment of a data communications network in accordance with the invention. Here, three aircraft **11**, **12**, **13** are provided, whose transceiver stations (not represented in **Fig. 2**) are respectively connected with each other via data links **31**, **32**. Two ground stations (or stations near the ground) **61**, **62** are additionally represented, which are respectively connected with one of the aircraft **11**, **12** via further data links **71**, **72**. A closed data communications network can therefore be created in the example represented in **Fig. 2**, wherein a completely interception-secure and interference-secure data transmission between two ground stations **61**, **62** is possible over very large distances.

Figs. 1 and **2** show that it is possible to create any arbitrary data communications networks in accordance with the invention in that any arbitrary number of aircraft **11**, **12**, **13** and ground stations **61**, **62** are suitably connected by means of laser- optical data links. As already mentioned, an interruption-free optical data link **31**, **32** is essential for the functioning of the data communications network. An optical link which is interruption-free over great distances, can typically, but not necessarily, be assured above the cloud tops **41**. For this reason the aircraft **11**, **12**, **13** connected with each other via data links **31**, **32** must fly at least high enough that the respective data links **31**, **32** between them are dependably arranged above the cloud tops **41** (**d4 > d2**).

Fig. 3 shows a diagram indicating the maximum track distances (**d1**) between two aircraft as a function of the flight level (**d3**) and the cloud tops (**d2**). It turns out that, with assumed cloud tops at **12** km and a flight level of **16** km, a maximum distance of approximately **500** km results between the two aircraft, while at a flight level of **30** km the free distance nearly doubles.

To create the data communications network in accordance with the invention, aircraft **11**, **12**, **13** were used in **Figs. 1** and **2**, which are designed for flying at great altitude. Such high- altitude aircraft, which as a rule are jet-propelled, have a service ceiling which mostly lies high above the maximum cloud tops. However, in every case the aircraft should have a ceiling of more than **12,000** m. It would also be conceivable to use captive balloons in place of aircraft. Very great altitudes, as far as up into the stratosphere, can be attained by means of captive balloons.

However, these aircrafts can also be designed as so-called unmanned drones, such as are often employed for reconnaissance purposes in crisis zones.

WHAT IS CLAIMED IS:

1. A wireless data communications system

- with a plurality of flying objects (**11**, **12**, **13**) capable of changing their position, which are located in a common, limited area of the earth's atmosphere, or at the distance of the earth atmosphere from the surface (**51**) of the earth,

- with at least one optical transceiver station (**21**, **22**) in each flying object (**11**, **12**, **13**),

each of which can be connected interference-free by means of first wireless data links (**31**, **32**) which are designed at least partially as laser-optical data links,

- with at least one fixed station (**61**, **62**) on or near the ground,

which can be connected with at least one transceiver station (**21**, **22**) via second wireless connections (**71**, **72**).

2. The wireless data communications network in accordance with claim **1**,

characterized in that

at least one of the transceiver stations (**21**, **22**) is designed for bi-directional data transfer and has an optical receiving unit and an optical transmitting unit for this purpose,

wherein the optical transmitting unit contains means for optical data modulation, a laser unit and an optical output amplifier and, wherein the optical receiving unit has a reception amplifier and means for optical data modulation.

3. The wireless data communications network in accordance with one of the preceding claims,

characterized in that

the transceiver stations (**21**, **22**), which are respectively coupled with each other via the first data links (**31**, **32**), have means for position stabilization and/or means for tracking the optical beam, which assure an interruption-free optical data connection (**31**, **32**) in case of slight vibrations and/or relative movements between the transceiver stations (**21**, **22**).

4. The wireless data communications network in accordance with one of the preceding claims,

characterized in that

at least one of the transceiver stations (**21**, **22**) is seated freely pivotable in space in such a way that this transceiver station (**21**, **22**) can be coupled via first data links (**31**, **32**) with any arbitrary transceiver station (**21**, **22**).

5. The wireless data communications network in accordance with one of the preceding claims,

characterized in that

the data transfer via the first data links (**31**, **32**) takes place by means of a broadband laser beam.

6. The wireless data communications network in accordance with claim **5**,

characterized in that

the data transmission rate of the broadband laser beam is at least several, preferably **25**, Mbit/sec.

7. The wireless data communications network in accordance with one of the preceding claims,

characterized in that

the flying objects (**11**, **12**, **13**) are high-altitude aircraft with a maximum flight level of at least **10,000** m.

8. The wireless data communications network in accordance with one of the preceding claims,

characterized in that

respectively two flying objects (**11**, **12**, **13**), which are optically coupled with each other by means of a data transfer, are essentially at the same flight level, and that the first data link (**31**, **32**) between these two flying objects (**11**, **12**, **13**) is arranged in relation to the ground respectively above the cloud tops (**41**).

9. A method for operating a data communications network in accordance with one of the preceding claims, having the following method steps:

(**a**) a data transfer is performed between at least two transceiver stations (**21**, **22**), each provided in flying objects (**11**, **12**, **13**), via the first data links (**31**, **32**), wherein an optical laser signal is used at least in sections for the data transfer,

(**b**) then a wireless data transfer between at least one transceiver station (**21**, **22**) and a station (**61**, **62**) on near the ground takes place via the second data links (**71**, **72**), wherein a data signal is received from the respective transceiver station (**21**, **22**) and/or is transmitted to the respective transceiver station (**21**, **22**).

10. The data transmission method in accordance with claim **9**,

characterized in that

the data transfer in method step (**b**) takes place by means of data-modulated laser signals.

11. The data transmission method in accordance with claim **9**,

characterized in that

the data transfer in method step (**b**) takes place by means of radio link signals.

12. The data transmission method in accordance with one of claims **9** to **11**,

characterized in that

that in method step (**a**) additional flying objects (**11**, **12**, **13**) are employed for data transmission when needed.

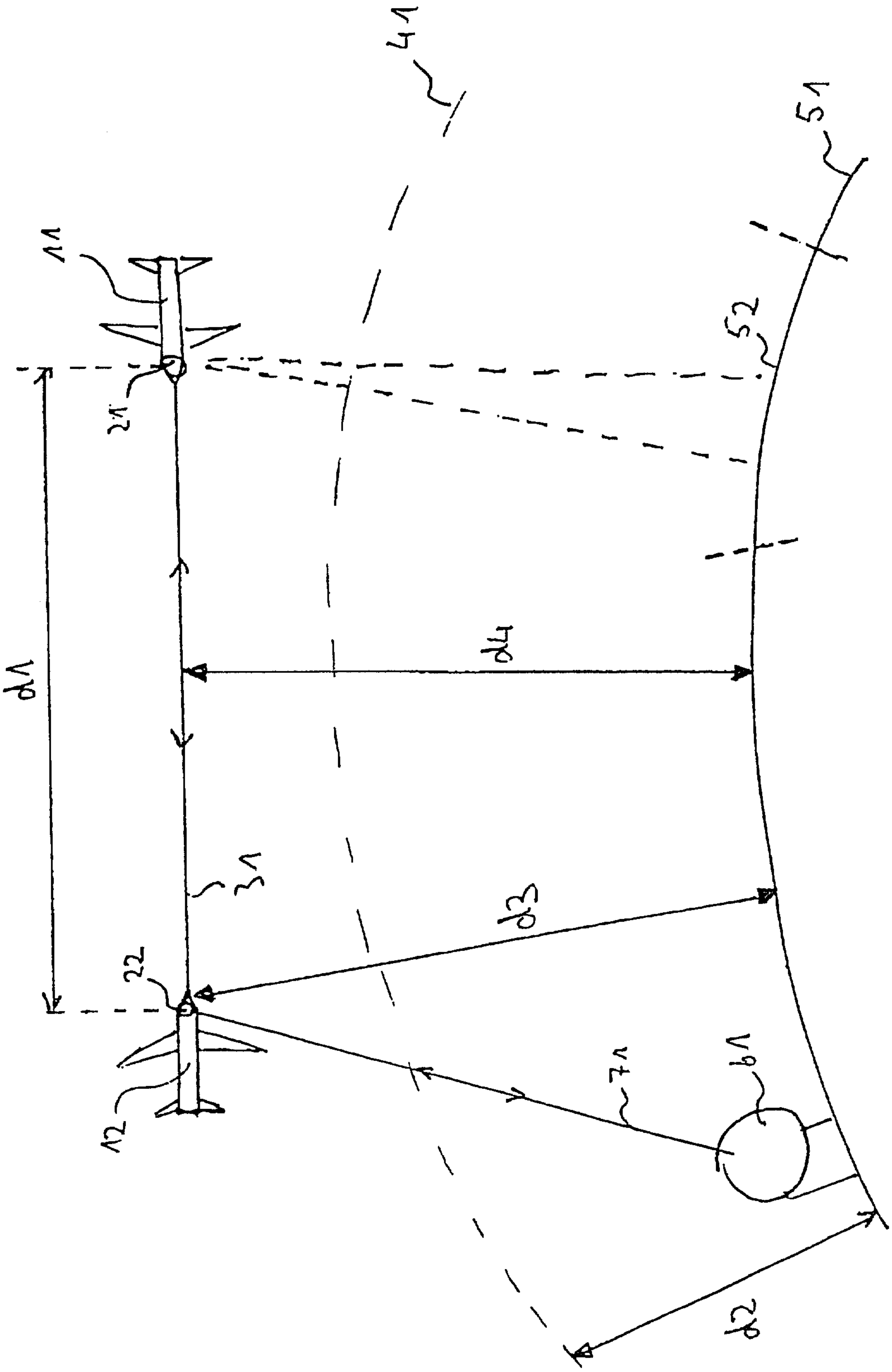


Fig. 1

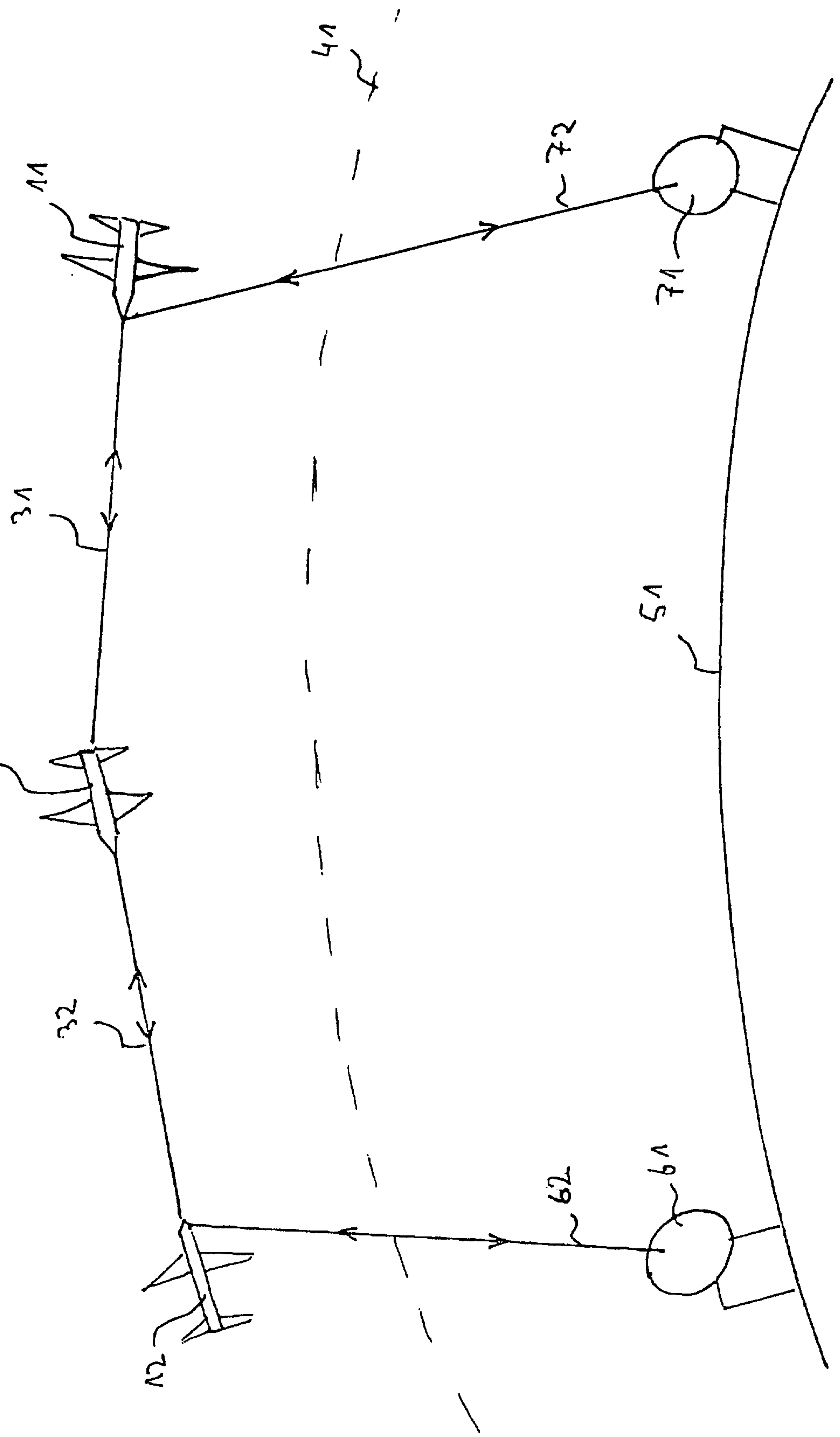


Fig. 2

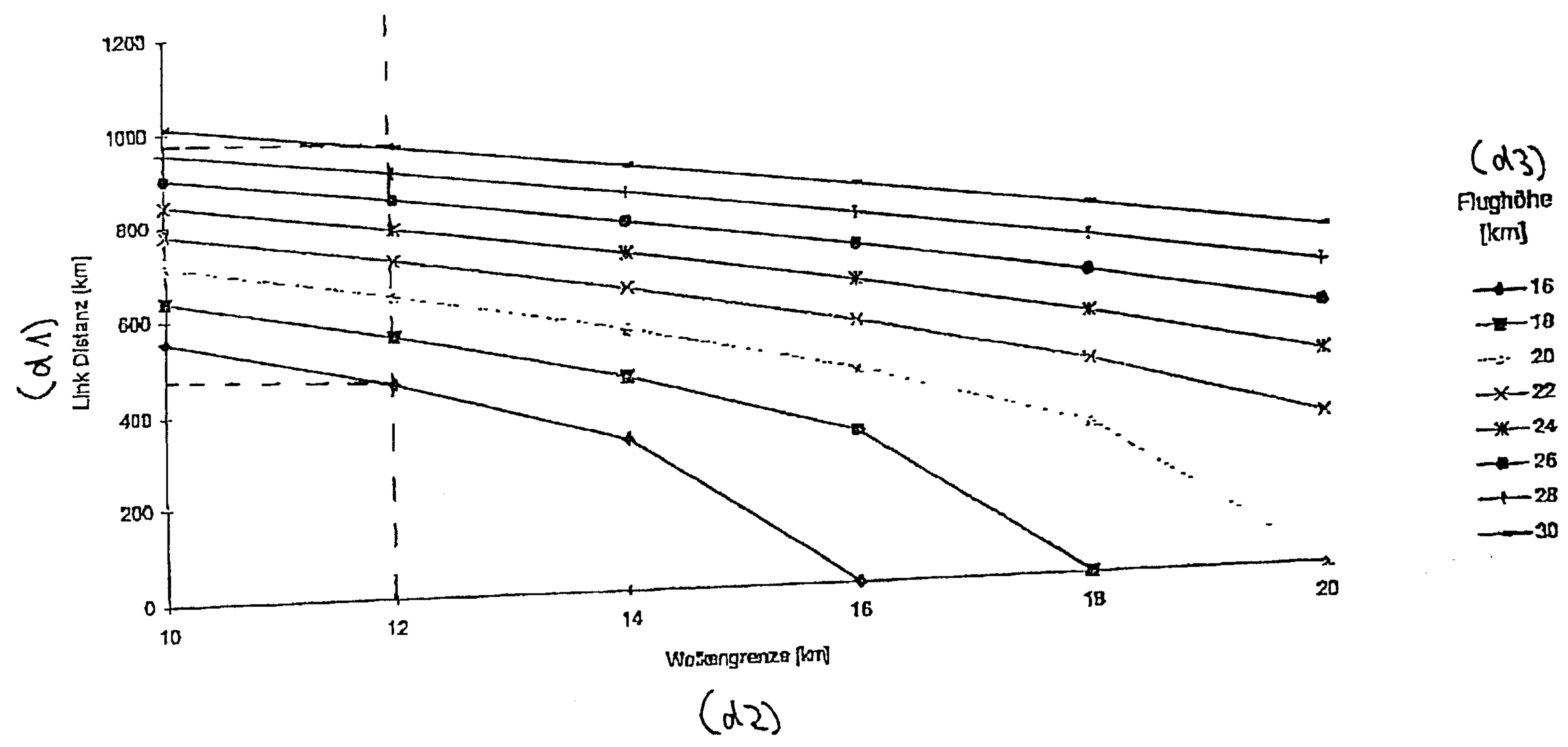
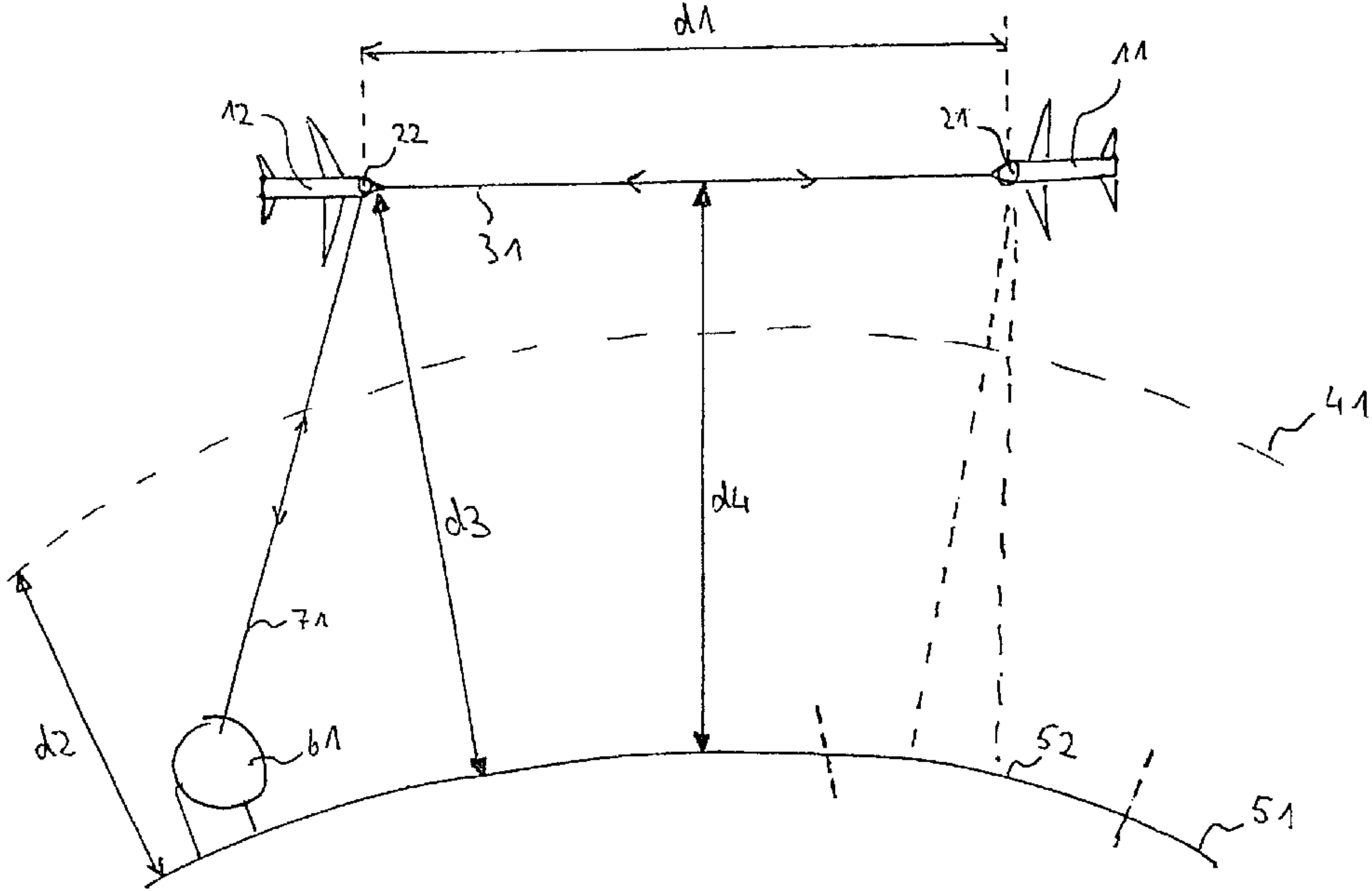

1200
1000
800
600
400
200
0
Link Distanz [km]
(d1)
10
12
14
16
18
20
Wolkengrenze [km]
(d2)
(d3)
Flughöhe
[km]
16
18
20
22
24
26
28
30

Fig. 3



d1
11
12
22
21
31
41
d4
d3
71
d2
61
52
51