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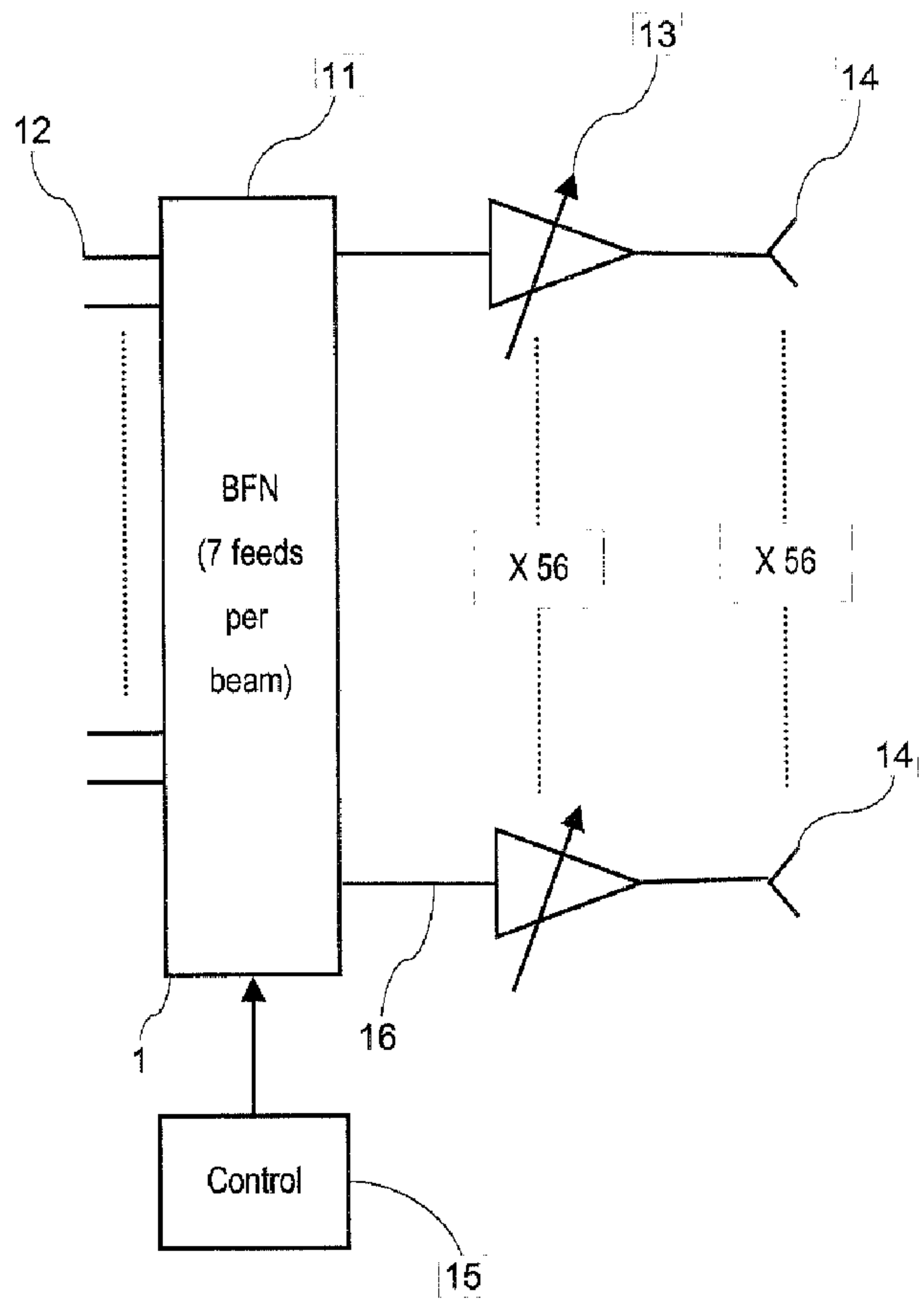
(54) Titre : ANTENNE DE SATELLITE DE COMMUNICATION MULTIFAISCEAU AVEC COMPENSATION DE DEFAILLANCE
(54) Title: MULTI-BEAM COMMUNICATION SATELLITE ANTENNA WITH FAILURE COMPENSATION



(57) Abrégé/Abstract:
A radio frequency radiation module is provided. The module comprises: a beam forming network capable of applying a signal including contributions to several beams, to several channels; each channel comprising a high power amplifier without redundant

(57) Abrégé(suite)/Abstract(continued):
units, and an antenna radiating feed connected to the output of the amplifier. The beam forming network comprises a device for selective compensation for failure of one of the channels, increasing the power of the contribution of at least one of the said signals to a beam for which the radiation is affected by the failure. Embodiments of the module provided may reduce losses, and the cost, volume and mass of an antenna to be put into orbit and provided with failure compensation functions.

ABSTRACT

A radio frequency radiation module is provided. The module comprises: a beam forming network capable of applying a signal including contributions to several beams, to several channels; each channel comprising a high power amplifier without redundant units, and an antenna radiating feed connected to the output of the amplifier. The beam forming network comprises a device for selective compensation for failure of one of the channels, increasing the power of the contribution of at least one of the said signals to a beam for which the radiation is affected by the failure. Embodiments of the module provided may reduce losses, and the cost, volume and mass of an antenna to be put into orbit and provided with failure compensation functions.

MULTI-BEAM COMMUNICATION SATELLITE ANTENNA WITH FAILURE COMPENSATION

BACKGROUND OF THE INVENTION

This invention relates to multiple beam communication satellite antennas and particularly a radiation module of a multiple beam communication satellite antenna capable of compensating for failures of its high power amplifiers and with flexible allocation of power to the beams.

A known antenna of the multiple focussed beams type with failure correction means is known. The front end of this antenna comprises a beam forming network (subsequently called a BFN) supplying input signals to a set of multiport amplifiers (subsequently called MPA). There are as many MPA as the maximum number of radiating feed used by any beam. Every beam uses one radiating feed belonging to each of the MPAs. The MPA has an input matrix separating signals corresponding to each input port, through an input matrix such that all beam signals are amplified by a set of high power amplifiers (subsequently called HPA) connected on the output side. Thus, independently of the beam power distribution between different input ports, an equal load is obtained for all HPAs that belong to the same MPA. Depending on the input port considered, the input matrix generates different relative phases at HPA inputs. An output matrix is connected to the output of HPAs and once again separates signal belonging to each input port, and applies them to the corresponding output port. This antenna transmit front end architecture is called multimatrix in the literature.

This antenna has HPA failure correction means. Thus, the antenna has redundant HPAs and redundancy circuits that will make the necessary switchings to replace a failed HPA in service by a redundant HPA. Thus, the total radio frequency power can be maintained.

There are several problems with this antenna. Redundancy circuits require a significant number of RF switches and redundant HPAs. Consequently, electrical losses, the mass, size, complexity, probability of failure and cost of the antenna are high. These disadvantages are more serious because the antenna is a mass that can be installed on a satellite and put into orbit.

Furthermore, high losses are caused by the accumulation of losses in the matrices, in the redundancy circuits, in wave guides, in insulators and in radiation filters, particularly in the Ku and Ka bands.

Due to the large size of the antenna, a wave guide or long coaxial cables are used to connect the antenna radiating feeds, leading to additional losses.

Furthermore, the antenna requires good phase and amplitude tracking between the different HPAs, so as to guarantee good isolation of RF beams. This problem increases with the operating frequency and is very acute in the Ka band. Consequently, phase and amplitude control tracking elements are required to correct phase and amplitude tracking errors due to temperature and aging. Furthermore, after each modification to the configuration of the redundancy circuit, phase and amplitude tracking of the MPA structure must be readjusted so as to guarantee good isolation of the RF beam.

Operation of HPAs in multi-carrier mode requires a reduction of the output back-off (OBO) power equal to more than 4 dB to obtain acceptable linearity performances. This problem is worsened by the fact that assignment of different powers to the different beams and due to the excitation dynamics of multiple radiating feeds contributing to forming each beam.

MPAs have been successfully used in the L and S bands in different missions. However, it is difficult to use the MPA concept at higher frequencies (Ku and Ka bands) because the problems mentioned above are further amplified. It is well known that phase and amplitude tracking errors are limited by the use of large MPAs (for example 16 x 16). However, redundant HPA amplifiers and the associated switching matrices are still necessary to maintain power and beam isolation within acceptable limits.

SUMMARY

In accordance with an aspect, the invention relates to a radiation module for a multiple beam communication satellite antenna that addresses one or several of these disadvantages. More precisely, a radio frequency radiation module for a spatial telecommunication antenna is provided, the module comprising:

- a beam forming network capable of applying a signal including contributions to several beams, to the input of several channels;

- each channel comprising a high power amplifier with an adjustable bias point and an antenna radiating feed connected to the output of the high power amplifier;

- the beam forming network comprising a device for selective compensation for failure of one of the channels, increasing the power of the contribution of at least one of the said signals to a beam for which the radiation is affected by the failure.

According to one variant, the compensation device includes a reception input for a remote control signal, and the increase in the power of the contribution is made as a function of the received signal.

According to yet another variant, the beam forming network includes a contribution to the same beam in signals applied to several channels.

According to another variant, each of the said amplifiers is provided with an adjustable power supply with a reception input of a remote control signal and at least one output for application of an amplifier bias point adjustment voltage as a function of the said control signal.

According to another variant, the amplifiers are travelling wave tube amplifiers (subsequently called TWTA).

According to one variant, the adjustment output includes an output connected to the anode of the amplifier and an output connected to the amplifier collector.

According to one alternative, the amplifiers are semiconductor amplifiers.

It would also be possible for the initial bias point of the amplifiers to be adjusted such that the output power of the amplifier is at least 3 dB less than its maximum output power.

The invention also relates to a spatial telecommunication antenna comprising such a radiation module.

In accordance with another aspect, the invention is also related to a method of compensating for a failure of one channel of such a module, that includes steps for:

- determination of one of the module channels having a failure;

- determination of a beam of the module for which the radiation is affected by the channel failure, and determination of a signal with a contribution to this beam;

- sending of a beam compensation control signal, remotely from the module, towards the input of the compensation device;

- increase in the power of the contribution of at least one of the said signals to the said beam as a function of the compensation control signal, by the beam forming network.

The antenna may previously be inserted into orbit.

According to one variant, the method also includes steps for:

- sending of a beam compensation control signal, remotely from the module, towards the input of the amplifier power supply of a channel contributing to this beam;

- application of an adjustment voltage of the bias point of the said amplifier as a function of the said compensation control signal, so as to increase the amplifier output power.

According to yet another variant, this method includes the following steps:

- sending of a control signal to modify the lateral lobes of a beam, remotely from the module, towards the reception input of the beam forming device;

- modification of at least one contribution to a beam in a signal applied to a channel, so as to modify the lateral lobes of this beam.

In accordance with another aspect, the invention relates to a method of compensating for a failure of one channel of a radio frequency radiation module comprising a beam forming network capable of applying a signal including contributions to several beams to an input of several channels; each channel comprising a high power amplifier with an adjustable bias point and an antenna radiating feed connected to the output of the high power amplifier; the beam forming network comprising a compensation device for selective compensating for failure of one of the channels by increasing the power of the contribution of at least one of the signals to a beam for which the radiation is affected by the failure. The method comprises the steps of: determining one channel of the module having a failure; determining a beam of the module for which radiation is affected by the channel failure, and determining a signal with a contribution to this beam; sending a beam compensation control signal, remotely from the module, towards an input of the compensation device; increasing by the beam forming network a contribution power of at least one of the signals to the beam as a function of the compensation control signal.

BRIEF DESCRIPTION OF THE DRAWINGS

Other specific features and advantages of the invention will become clearer after reading the following description that is given as a non-limitative example and with reference to the figures in which:

- Figure 1 is a schematic representation of an example of a multi-beam antenna radiation module;

- Figure 2 is a schematic representation of radiating feeds of a radiation array;

- Figure 3 is a diagram of powers at the input to an amplifier associated with a radiating feed, the powers corresponding to different beams in the absence of an amplifier failure for these beams;

- Figure 4 is a diagram of powers at the input to the amplifier in Figure 3, the powers corresponding to the different beams at the time of the failure of an amplifier for one of these beams;

- Figure 5 illustrates an example of connections for adjustment of the bias point of a TWTA type HPA.

DETAILED DESCRIPTION

The invention proposes a radio-frequency radiation module for a spatial telecommunication antenna. A BFN is designed to apply a signal with contributions to different beams, to the input of several channels. Each channel has an HPA and a radiating feed connected to this HPA. The BFN comprises a device for compensation of the failure of one of the channels that affects at least one beam. This device increases the contribution of one of the signals to this beam.

Thus, the failure of one channel is compensated without the need for redundancy circuits or MPAs. Therefore, the radiation module does not need redundant HPAs and the associated RF switches. Consequently electrical losses, the mass, size, complexity, probability of failure and cost of the radiation module according to the invention are strongly reduced. Furthermore, losses in the Ku and Ka bands are also strongly reduced. Furthermore, the compact size of the antenna using the radiation module according to the invention provides a means of reducing the length of a wave guide or coaxial cables that can be used for the connection of radiating feeds. Furthermore, the phase and amplitude control in HPAs is very much facilitated.

Figure 1 schematically shows an example of a radiation module 1 of a multi-beam telecommunication antenna for space use. This module 1 includes a BFN 11 with data inputs 12, known in itself. The BFN is capable of applying a signal corresponding to several channels 16 containing contributions to several beams to be radiated. Each channel has an HPA with an adjustable bias point 13 and an antenna radiating feed 14 connected to the output from the HPA. The BFN 11 comprises a selective failure compensation device for one of the channels. For a beam for which the radiation is affected by a failure, the device increases the power of the contribution to this beam in a signal applied on one of the channels.

One of the inputs 15 of the BFN 11 may be provided so as to receive control signals sent from a distance from the module. The control signal may typically be sent from a land station to an orbital antenna in which the module is installed. This control signal may include all the necessary information so that the BFN increases the power of the contribution accordingly. The received control signals may be used to adjust phase and amplitude settings made by the BFN on signals applied to the channels. In particular, this readjustment may help to readjust beam shape characteristics (for example the ration or magnitude of the side lobes).

The BFN 11 will generally be designed to include a contribution to a same beam in signals applied to several channels.

A low power level BFN will preferably be used.

Types of signals output by the BFN and the types of connection between the BFN and the channels may be different. Thus, the BFN is not necessarily directly connected to HPAs. The BFN may also be made in the form of a numeric base band processor with different possible architectures. The BFN may also generate IF or RF signals.

The HPAs used may be of the semiconductor type or of the travelling wave tube type.

A Travelling Wave Tube Amplifier will be used in preference with a bias point that could be controlled. These amplifiers will subsequently be denoted with the abbreviation TWTA. For example, remote controllable TWTAs will be used. Figure 5 illustrates a channel using an example of such an HPA.

The input 511 of the HPA 51 may be connected to the BFN and its output 512 may be connected directly to the radiating feed 53. The HPA is provided with an adjustable power supply 52. This power supply 52 has a reception input 521 of a remote control signal and has an output interface for application of an adjustment voltage for bias point of the amplifier. The output interface is used to apply an adjustment voltage as a function of a received control signal. Thus, the HPA bias point will be adjusted as a function of the increase in power of some contributions in the signal output by the BFN.

For example, the output interface may have a connection 513 at the anode of the amplifier 51, a connection to the amplifier collector 514, and a connection to the control gate 515 or the helix of the amplifier.

In general, amplifiers with bias point adjustment are also used to reconfigure the power per beam by varying their saturation power. In the example in Figure 5, the power may be regulated using voltages applied by the power supply 52 to the anode 513 and to the collector

514. The adjustment of the anode voltage provides a means of adjusting the saturation of the radio frequency power.

The radiation module illustrated in Figure 1 comprises 56 HPAs connected to 56 corresponding radiating feeds and its specific operation will be described in detail later. Figure 2 schematically illustrates a portion of a radiating feed array 21 in a configuration compatible with the module in Figure 1. In the example shown, it is assumed that a beam is normally formed by radiation by 7 radiating feeds. In this example, it is also considered that each radiating feed (apart from edge radiating feeds of the radiation array) normally provides a contribution to 7 beams. Therefore radiating feed groups corresponding to adjacent beams overlap. For simplification purposes, it will be considered that three adjacent radiating feeds are arranged at each of the vertices of an equilateral triangle.

Each radiating feed (apart from the edge radiating feeds of the radiation array) will provide a larger contribution for a beam and a smaller contribution for the other six beams, as will be described in detail later. Therefore each beam will normally be formed by a main contribution from one radiating feed and six other lesser contributions from six other radiating feeds.

Figure 3 illustrates a contribution of a radiating feed to its beams during normal operation. Figure 4 illustrates the contribution of this radiating feed to its beams during a failure of an adjacent radiating feed. The abscissas axis in Figures 3 and 4 does not identify frequencies but simply the different beams, the contributions to these beams possibly but not necessarily having different frequencies.

The upper case characters A to G identify radiating feeds. The lower case characters a to g identify a beam for which the contribution of the radiating feed with the same character is normally the greatest.

We will start by studying the beam g in normal operation in a simplified case. The beam g is formed by contributions of radiating feeds A to G. In this case, it will be considered that the radiating feed G contributes half of the power of beam g. We will also assume that each radiating feed A to F contributes 1/12 of the power of the beam g. The radiating feed G will contribute 1/12 of the power of beams A to F. Obviously, if the radiation power of the beams is different, the power levels of each of these contributions will be adapted accordingly. Figure 3 illustrates the contribution of radiating feed A to different beams. It is seen that radiating feed A contributes half of its power to beam a, as illustrated by reference 31, and 1/12 of its power to beams b, g, f, h, i and j respectively, as illustrated by reference 32.

When the HPA of radiating feed G is defective, it will be considered that the power emitted by the radiating feed G is zero, in the most critical case. For beam g, the loss of radio frequency power can then be estimated at 3 dB and the loss of directivity at 2.5 dB. Thus, there is a loss of 5.5 dB on the EIRP. The loss of radio frequency power on beams a to f can be estimated at 0.4 dB, and the loss of directivity can be estimated at 0.5 dB. There is thus a loss of about 1 dB on the EIRP.

In this case, the radiation module will compensate for the failure of radiating feed G, by modifying the radiation powers of radiating feeds A to F, and modifying the contributions of these radiating feeds to different beams. The failure of the radiating feed G has an influence on beams a to g. For beam g, the 5.5 dB loss of the initial EIRPIs is compensated by an increase of 5.5 dB in the contribution of radiating feeds A to F to beam g. In the example of radiating feed A, this contribution is illustrated by reference 41. For beams b and f, the radiating feed A has an increase of 1 dB of its contributions, as illustrated by reference 42 in Figure 4. Finally, the radiating feed A increases its contribution to beam a by 1 dB, as illustrated by reference 43. The contributions of radiating feed A to beams h, i and j are unchanged, as illustrated by reference 44.

It is found that an increase in the global power of each adjacent radiating feed equal to 1.4 dB is sufficient to compensate for the lack of radiation from radiating feed G. It would thus be possible that HPAs will have a power margin of at least 3 dB during normal operation. One HPA can thus compensate for failures of several HPAs associated with adjacent radiating feeds. In the example described in detail, a margin of 3 dB is sufficient to compensate for the failure of at least two adjacent radiating feeds.

During normal operation, in the case in which the module only manages a single carrier per beam traffic, and with a distribution of contributions similar to those mentioned, it is found that a limited reduction of the output power is sufficient to obtain acceptable linearity performances. There is no inter-modulation between two large contributions, in other words two high power carriers. Therefore, non-linear distortions of low power carriers are avoided. This property also provides a means of reducing the global ratio between the radiated radio frequency power and the DC power supply. This ratio can be kept relatively constant for different radio frequency radiation powers. The following ratios were obtained in the simulations made with the above-mentioned parameters, by controlling the anode voltage and optimising the collector voltage:

Radio-frequency power	RF/DC ratio
143W	66%
110W	66%
72W	63.5%
44W	58%
14.3W	46%

Although the description provides a detailed and simplified example for several radiating feeds per beam, for a number of contributions per radiating feed and for a given power distribution between radiating feed contributions, the invention is obviously applicable for different values of these parameters. The distribution of the contribution between radiating feeds to a beam will obviously be dependent on optimisation of the antenna design. The distribution of contributions between radiating feeds could also be different from the described distribution.

What is claimed

1. A radio frequency radiation module for a spatial telecommunication antenna, comprising a beam forming network capable of applying a signal including contributions to several beams, to an input of several channels; each channel comprising a high power amplifier with an adjustable bias point and an antenna radiating feed connected to the output of the high power amplifier; the beam forming network comprising a device for selective compensation for failure of one of the channels, increasing the power of the contribution of at least one of said signals to a beam for which the radiation is affected by the failure.

2. The radiation module according to claim 1, wherein the compensation device includes a reception input for a remote control signal, the power of the contribution being increased as a function of the received signal.

3. The radiation module according to claim 1, wherein the beam forming network includes a contribution to the same beam in signals applied to several channels.

4. The radiation module according to claim 1, wherein each of said amplifiers is provided with an adjustable power supply with a reception input of a remote control signal and at least one output for application of an amplifier bias point adjustment voltage as a function of said control signal.

5. The radiation module according to claim 4, wherein the adjustable power supply includes an output connected to an amplifier anode of said amplifier and an output connected to an amplifier collector of said amplifier.

6. The radiation module according to any one of claims 1, 4 and 5, wherein the amplifiers are Travelling Wave Tube Amplifiers.

7. The radiation module according to claim 1, wherein the amplifiers are semiconductor amplifiers.

8. The radiation module according to claim 1, wherein the initial bias point of the amplifiers is adjusted such that the output power of the amplifier is at least 3 dB less than a maximum output power.

9. A spatial telecommunication antenna comprising a radiation module according to any one of claims 1 to 8.

10. A method of compensating for a failure of one channel of a radio frequency radiation module comprising a beam forming network capable of applying a signal including contributions to several beams to an input of several channels; each channel comprising a high power amplifier with an adjustable bias point and an antenna radiating feed connected to the output of the high power amplifier; the beam forming network comprising a compensation device for selective compensating for failure of one of the channels by increasing the power of the contribution of at least one of said signals to a beam for which the radiation is affected by the

failure, said method comprising steps of: determining one channel of the module having a failure; determining a beam of the module for which radiation is affected by the channel failure, and determining a signal with a contribution to this beam; sending a beam compensation control signal, remotely from the module, towards an input of said compensation device; increasing by the beam forming network a contribution power of at least one of said signals to said beam as a function of the compensation control signal.

11. The method according to claim 10, further comprising steps of: sending a beam compensation control signal, remotely from the module, towards an input of an amplifier power supply associated with an amplifier in a channel contributing to this beam; applying an adjustment voltage of the bias point of the amplifier in the channel contributing to this beam as a function of said compensation control signal, so as to increase an amplifier output power associated with the amplifier in the channel contributing to this beam.

12. The method according to claim 10, further comprising steps of: sending a control signal to modify the lateral lobes of a beam, remotely from the module, towards a reception input of a beam forming network; modifying at least one contribution to a beam in a signal applied to a channel, so as to modify a lateral lobes of this beam.

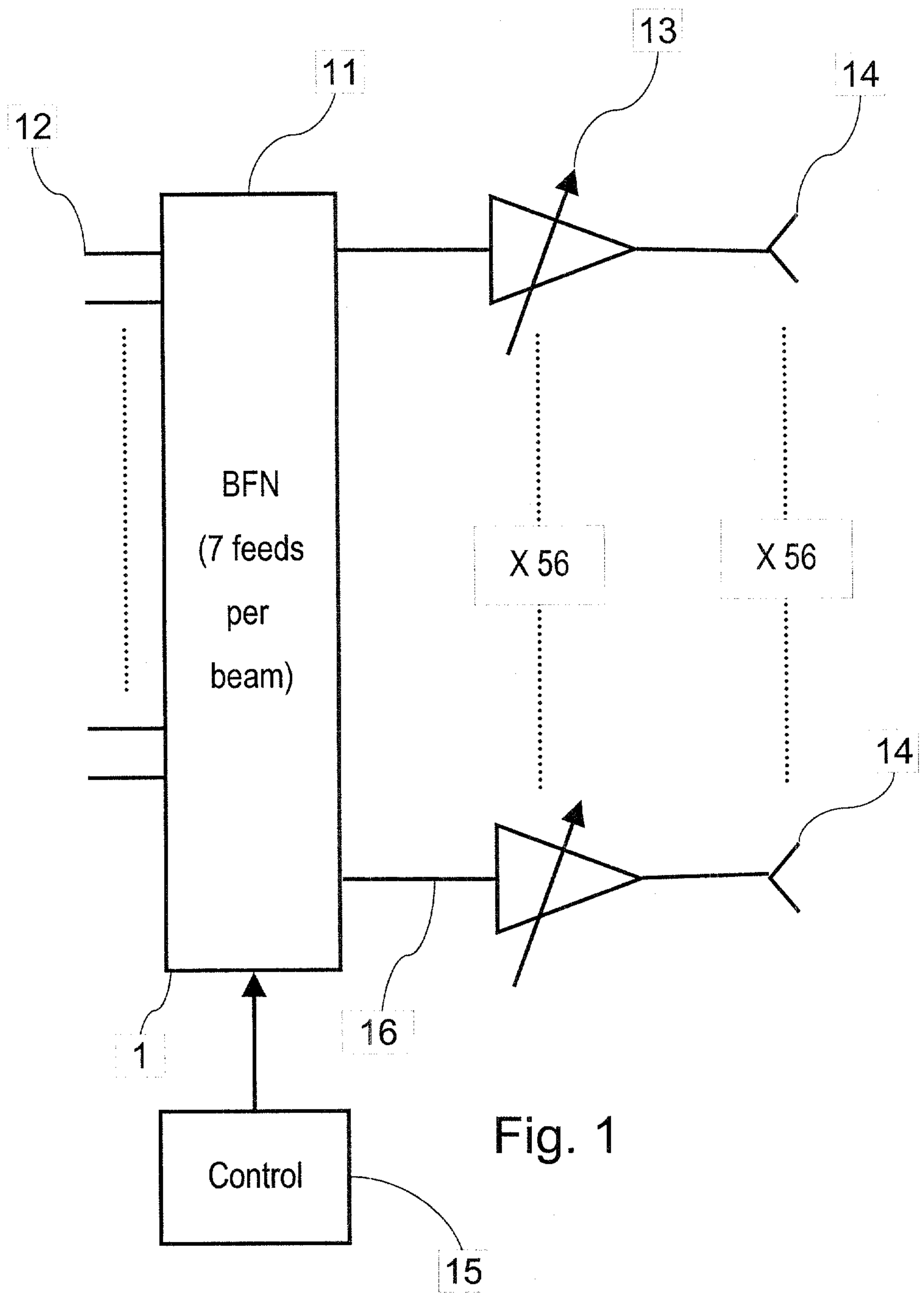


Fig. 1

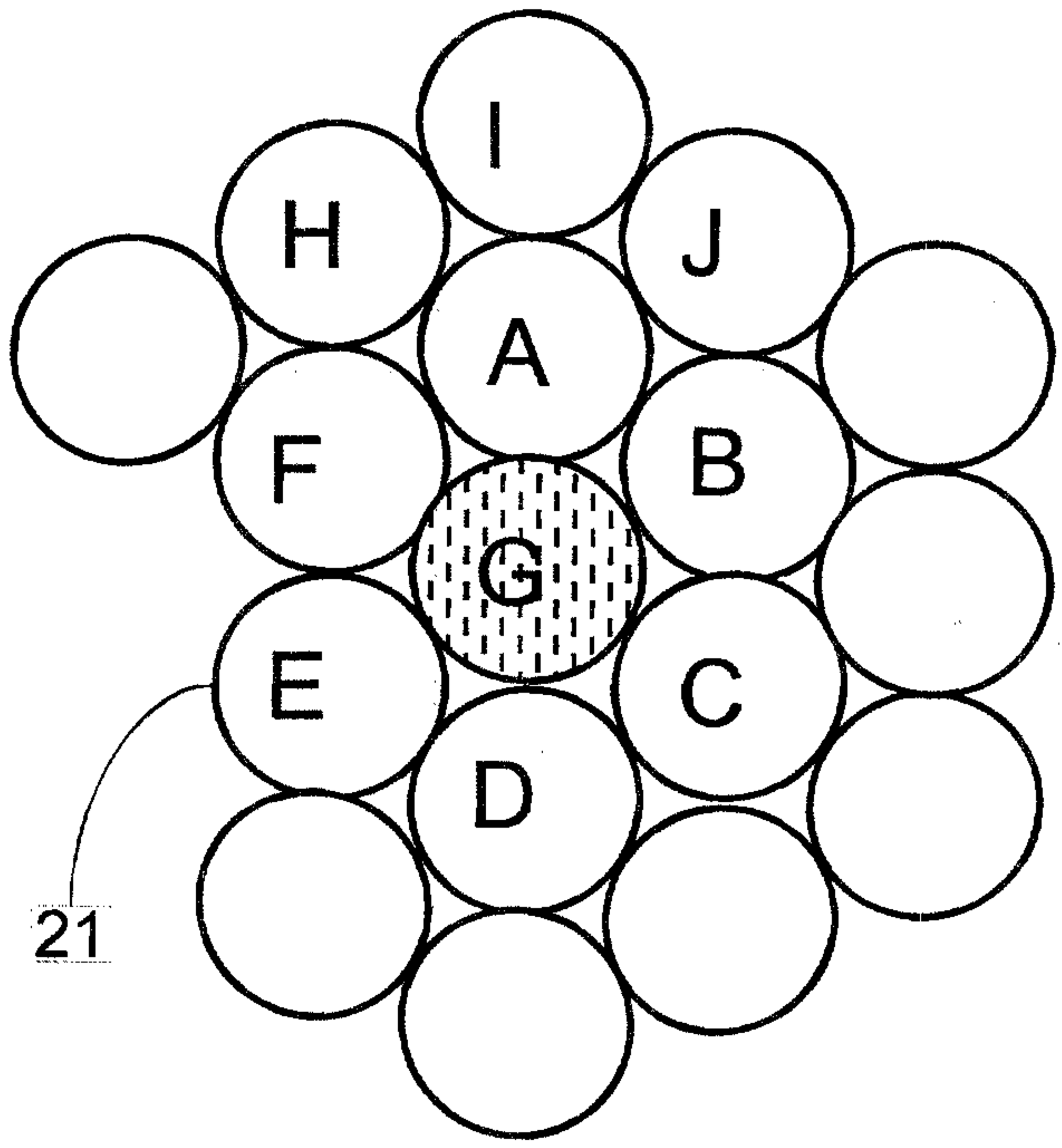


Fig. 2

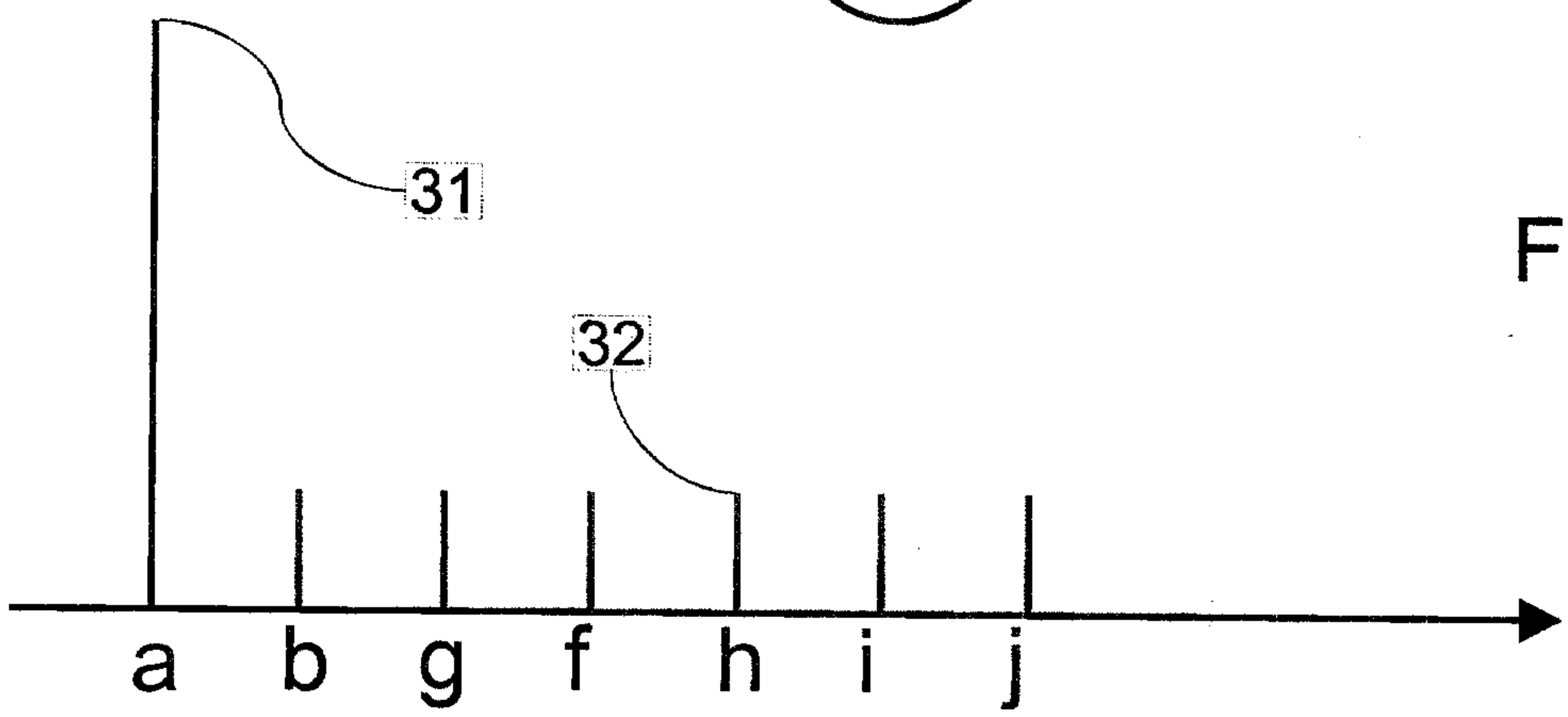


Fig. 3

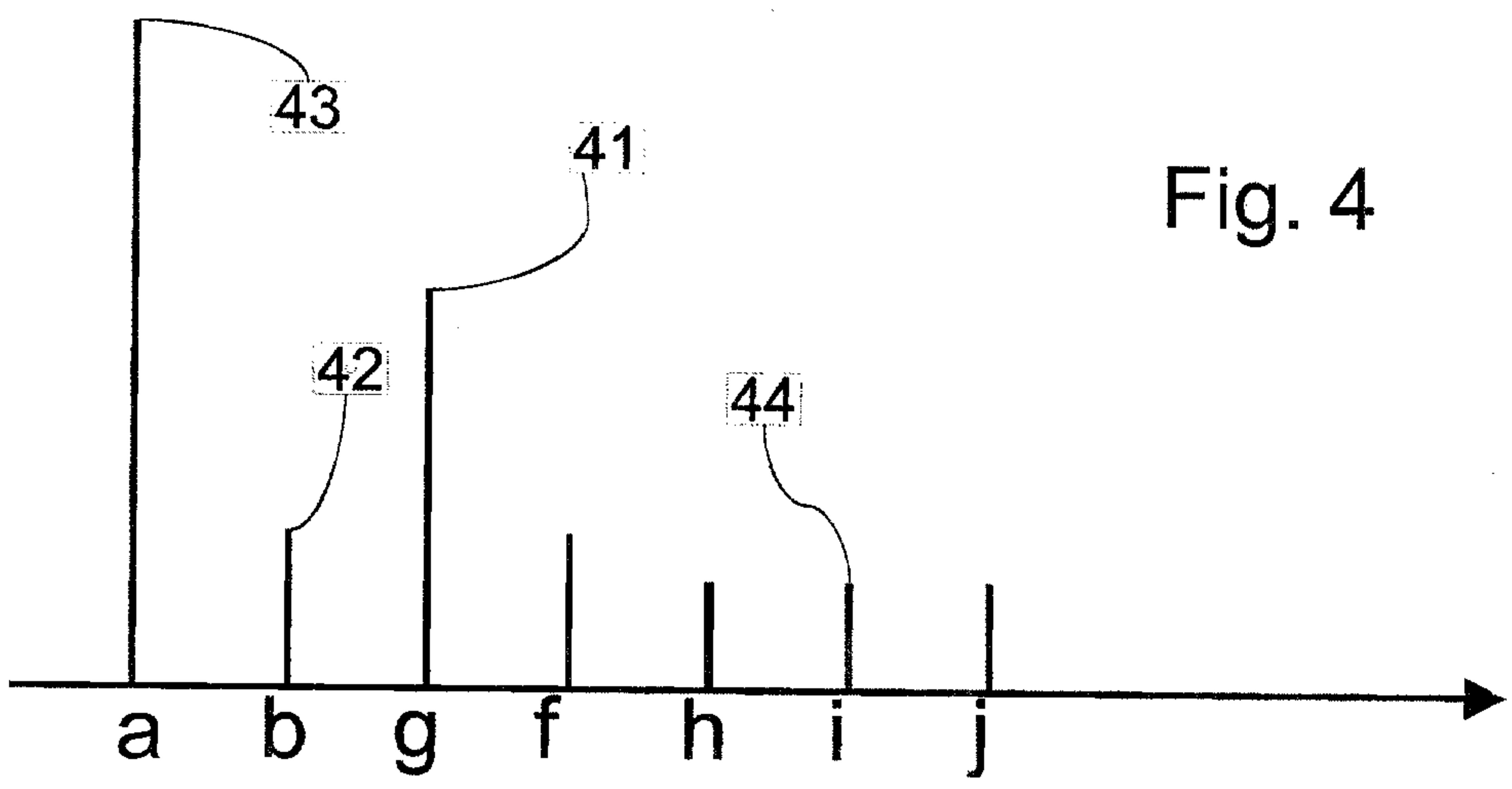


Fig. 4

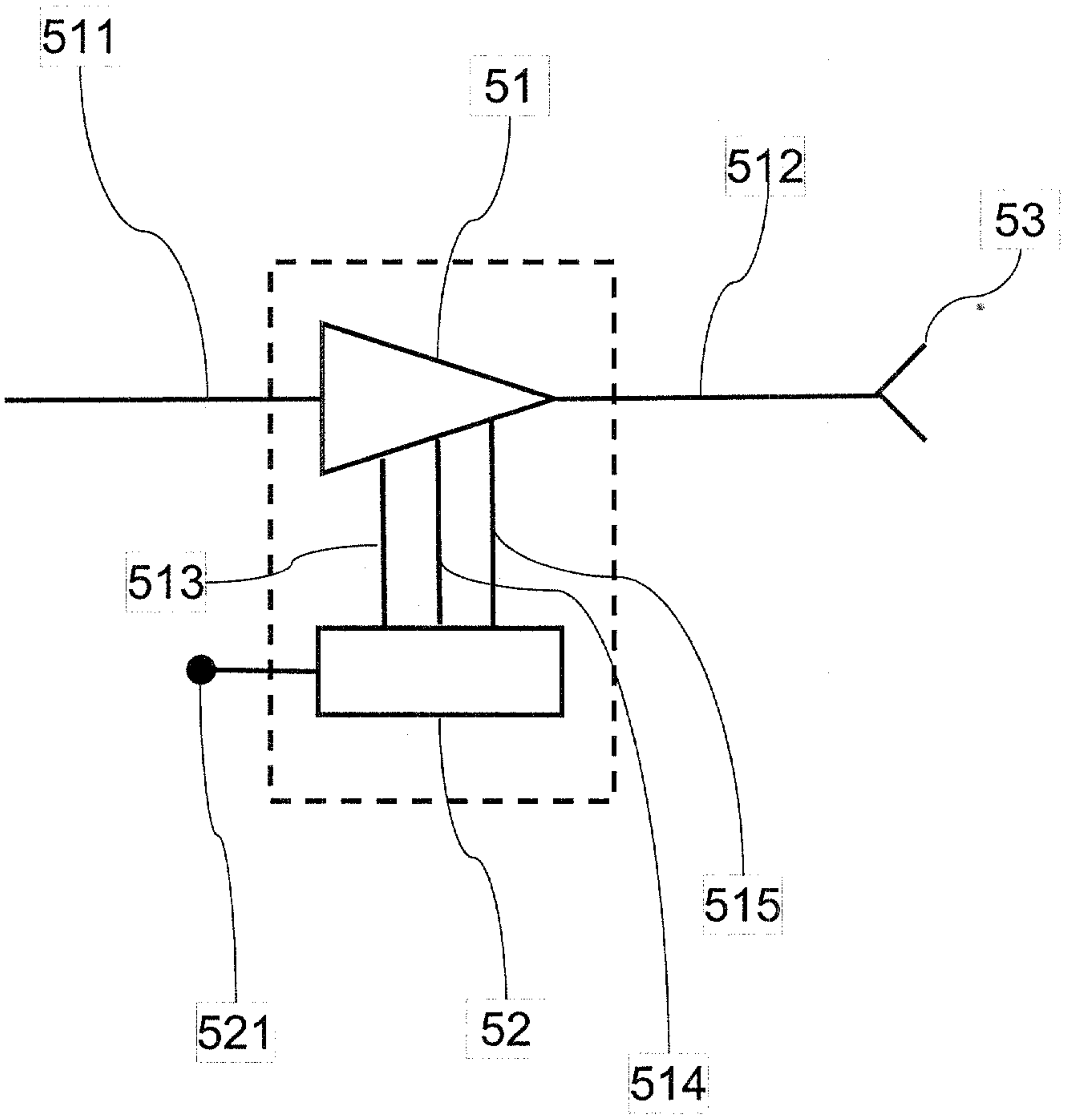
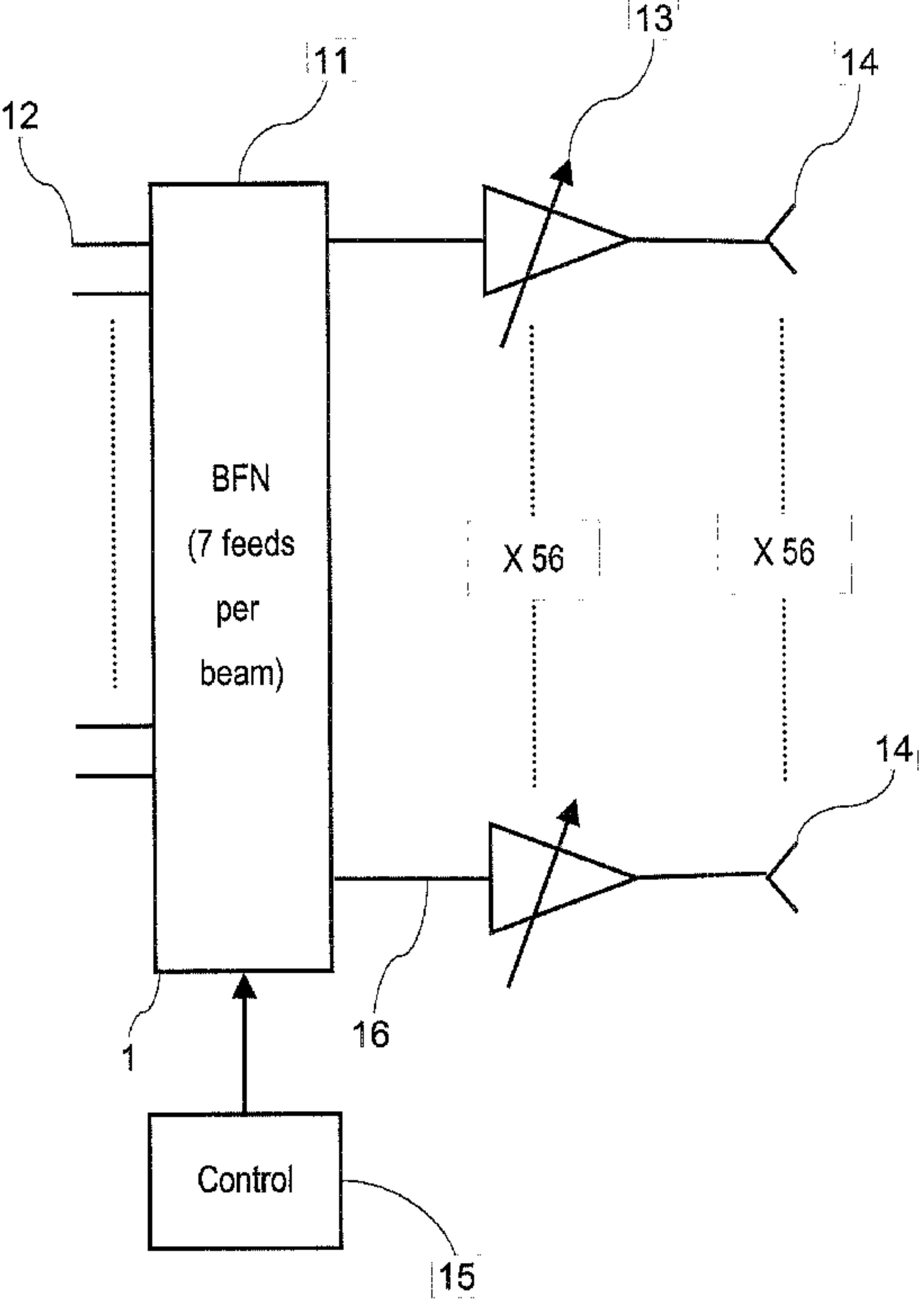


Fig. 5



13
11
14
12
BFN
(7 feeds
per
beam)
X 56
X 56
14
1
16
Control
15