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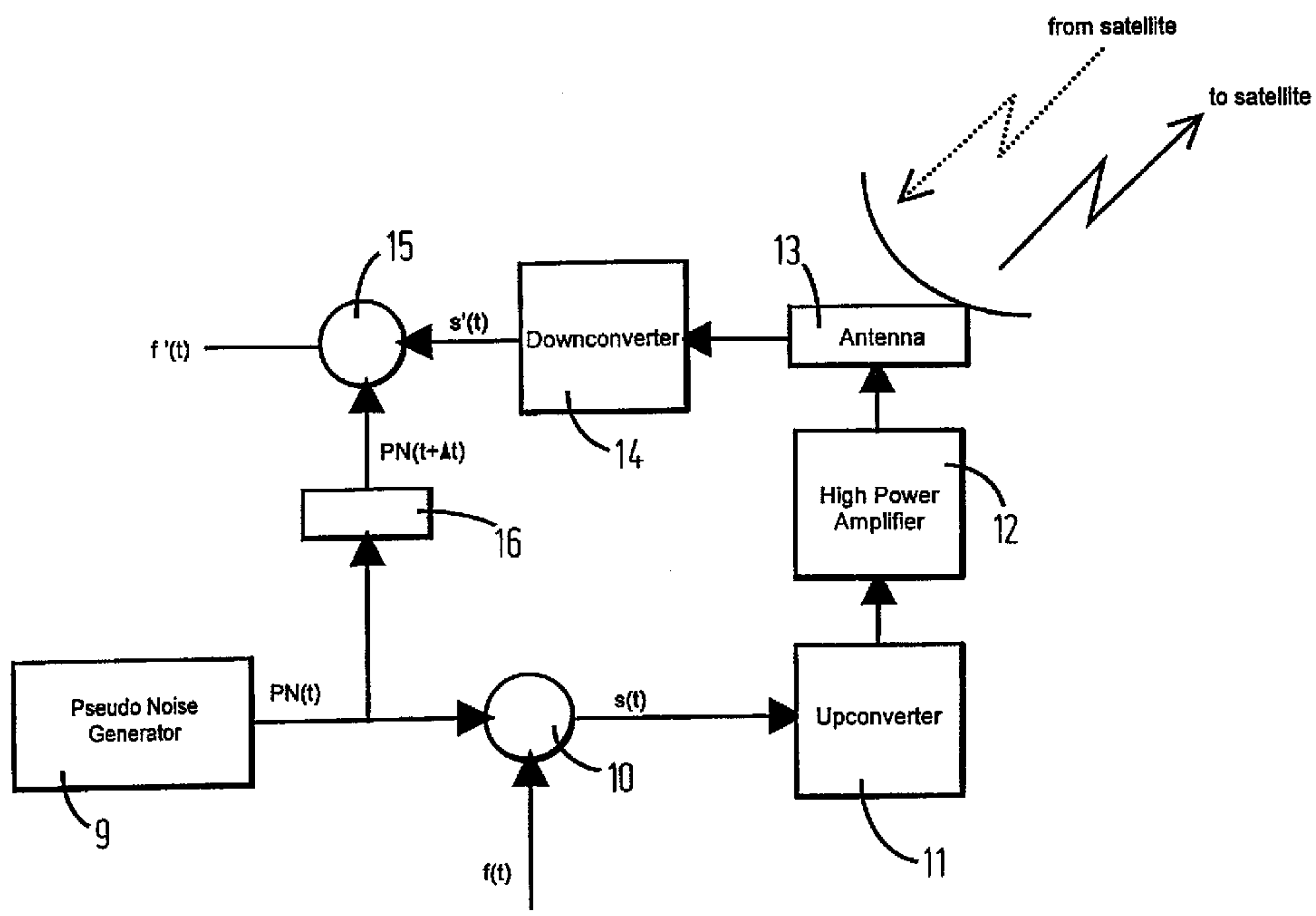
(54) **PROCEDE ET APPAREIL PERMETTANT DE DETERMINER LES CARACTERISTIQUES DES CONSTITUANTS D'UNE VOIE DE COMMUNICATION DANS DES CONDITIONS D'UTILISATION**

(54) **METHOD AND APPARATUS FOR DETERMINING CHARACTERISTICS OF COMPONENTS OF A COMMUNICATION CHANNEL UNDER LOAD**



(57) Pour déterminer les caractéristiques de constituants d'une voie de communication, par exemple d'un transpondeur dans un satellite de communication, un signal multiplex f(t) indépendant est modulé avec un signal de pseudo-bruit PB(t) et transmis par la voie de communication à un niveau inférieur au niveau d'un

(57) For determining characteristics of components of a communication channel, for example of a transponder in a communication satellite, a clean carrier signal f(t) is modulated with a pseudo noise signal PN(t) and transmitted through the communication channel at a level below the level of a payload signal which is

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signal de charge utile qui est transmis simultanément par la voie de communication. Le signal reçu s'(t) est mis en corrélation avec le même signal de pseudo-bruit PB(t) pour produire un signal multiplex récupéré f'(t). Le signal multiplex indépendant f(t) et le signal multiplex récupéré f'(t) peuvent tous deux être utilisés pour déterminer les caractéristiques désirées. Etant donné que le signal multiplex indépendant s(t) modulé PB est transmis à un faible niveau, il est possible d'effectuer des mesures sans interrompre le signal de charge utile.

transmitted via the communication channel simultaneously. The received signal s'(t) is correlated with same pseudo noise signal PN(t) to obtain a recovered carrier signal f'(t). Both the clean carrier signal f(t) and the recovered carrier signal f'(t) can be used to determine the desired characteristics. Since the PN modulated clean carrier signal s(t) is transmitted at a low level, it is possible to perform measurements without switching off the payload signal.

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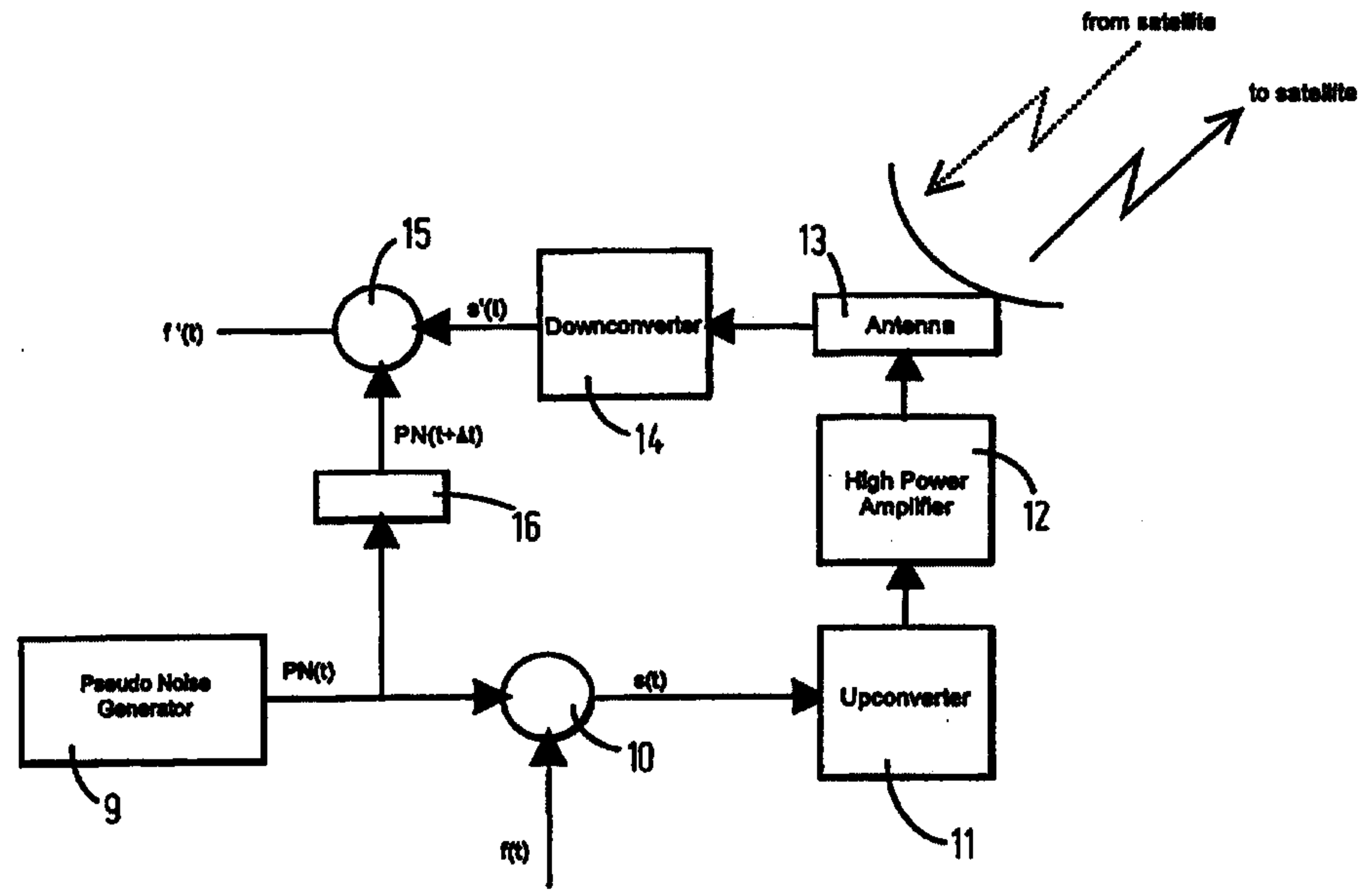

(57) Abstract

For determining characteristics of components of a communication channel, for example of a transponder in a communication satellite, a clean carrier signal f(t) is modulated with a pseudo noise signal PN(t) and transmitted through the communication channel at a level below the level of a payload signal which is transmitted via the communication channel simultaneously. The received signal s'(t) is correlated with same pseudo noise signal PN(t) to obtain a recovered carrier signal f'(t). Both the clean carrier signal f(t) and the recovered carrier signal f'(t) can be used to determine the desired characteristics. Since the PN modulated clean carrier signal s(t) is transmitted at a low level, it is possible to perform measurements without switching off the payload signal.

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Method and apparatus for determining characteristics of components of a communication channel under load

This invention relates to a method and an apparatus for determining characteristics of components of a communication channel, especially a transponder in a communication satellite under load.

The characteristics of a communication channel may change during the lifetime of the equipment used. Various tests may be performed not only at the beginning of but also repeatedly during the lifetime to verify that the communication channel meets predetermined specifications. Usually, these test are performed without normal traffic, i.e. without the communication channel being used for transmission of a communication signal. This scenario will be explained in the following in greater detail with reference to communication satellites but without limiting the invention disclosed further below to only this application although the invention is specifically applicable in this field.

In a communication satellite, a communication channel is set up by a transponder of the satellite comprising several components like a receiving antenna, an input demultiplexer, a power amplifier, an output multiplexer, and a transmitting antenna. Transponder characteristics, such as amplitude response and group delay, are measured not only at the beginning of life of the spacecraft on the ground and, after launch, in orbit but also during the lifetime. These measurements are conventionally carried out without normal traffic on the transponder, i.e. without a payload signal being transmitted to and being re-transmitted by the transponder.

The necessity of switching off the payload signal during tests represents a considerable drawback not only for the user of the transponder, since communication is interrupted, but also for the operator of the the satellite since the tests have to be performed in an expedited manner to keep the interruption as short as possible. In some cases it is impossible to interrupt communications via the communication channel so that the components of these channels cannot be tested after having enter into operation.

US-A-4.637.017 relates to monitoring the input power to a transponder of a TDMA communication sytellite system. In TDMA systems, only a single carrier frequency is present at the input of the travelling wave tube amplifier which can, therefore, be operated close to the saturation point of the TWT in the absence of non-linearity and intermodulation. In order to measure input-backoff, a monitoring station transmits a CW pilot signal within the amplifiers bandwidth. In the guard time between bursts, the monitoring station measures the unsuppressed pilot level output by the amplifier. While a ground station is transmitting an unmodulated carrier during carrier recovery or a carrier modulated at the clock frequency during clock recovery, the monitoring station measures the suppressed pilot level suppressed by the non-linear interaction of pilot and carrier. The amount of pilot suppression is related to the input power back-off of the carrier by a previously measured

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or a theoretically derived relationship. The carrier-to-suppressed noise ratio is determined by measuring the carrier level during the carrier recovery and by measuring the suppressed noise during carrier or clock recovery through a noise filter centered away from any transmitted signals or their intermodulation products.

DE-A-36 44 175 discloses a method for transmitting via a satellite data and auxiliary information for controlling the data channel or data network respectively. The auxiliary information is transmitted as a pseudo-noise sequence so that the same frequency can be used for data transmission and auxiliary information transmission.

It is an object of the present invention to provide a method and an apparatus for determining characteristics of components of a communication channel, especially a transponder of a satellite, without the necessity to interrupt traffic via the communication channel.

This object and other objects are achieved by a method for determining characteristics of components of a communication channel which is designed for transmitting a payload signal at a predetermined level, comprising: generating a first pseudo noise signal PN(t); modulating a clean carrier signal f(t) with said first pseudo noise signal PN(t) to generate a PN modulated clean carrier signal s(t); transmitting said PN modulated clean carrier signal s(t) through said communication channel at a level below the level of said payload signal; receiving a receive signal s'(t) corresponding to said PN modulated clean carrier

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signal s(t) after having traveled through said communication channel; correlating said receive signal s'(t) with said first pseudo noise signal PN(t) to generate a recovered carrier signal f'(t); and determining characteristics of components of the communication channel on the basis of a comparison of said clean carrier signal f(t) and said recovered carrier signal f'(t).

Advantageously, the level of said PN modulated clean carrier signal s(t) is at least 15 dB, preferably 25 dB or more below the level of said payload signal.

In a further embodiment, said first pseudo noise signal PN(t) is a binary pseudo noise sequence, which is preferably generated by means of a feed back shift register.

A chiprate of said first pseudo noise signal PN(t) is less than 5 MChip/s and preferably less than or equal to 2,5 MChip/s.

In a further embodiment, said correlating of said receive signal s'(t) and said first pseudo noise signal PN(t) is achieved by delaying said first pseudo noise signal PN(t) and multiplying the delayed first pseudo noise signal PN(t) and said receive signal s'(t).

To generate a reference, the method according to the invention further comprises: generating a second pseudo noise signal $PN_R(t)$; modulating a reference carrier signal $f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a PN modulated reference carrier signal $s_R(t)$; transmitting said PN modulated reference carrier signal $s_R(t)$. through said communication channel at a level below the level of said payload signal; receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through said communication channel; correlating said reference receive signal $s_R'(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a recovered reference carrier signal $f_R'(t)$; and determining characteristics of components of the communication channel

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also on the basis of a comparison of said reference carrier signal $f_R(t)$ and said recovered carrier signal $f_R'(t)$.

Advantageously, the level of said PN modulated reference carrier signal $s_R(t)$ is at least 15 dB, preferably 25 dB or more below the level of said payload signal.

In a further embodiment, said second pseudo noise signal PN(t) is a binary pseudo noise sequence which is preferably generated by means of a feed back shift register.

In a further embodiment, said correlating of said reference receive signal $s_R'(t)$ and said second pseudo noise signal $PN_R(t)$ is achieved by delaying said second pseudo noise signal $PN_R(t)$ and multiplying the delayed second pseudo noise signal $PN_R(t)$ and said reference receive signal $s_R'(t)$.

The method of the invention as characterized above is especially applicable when said communication channel is a transponder of a communication satellite. Said PN modulated reference signal $s_R(t)$ may be transmitted through the same transponder of the satellite, but then said second pseudo noise signal $PN_R(t)$ must not correlate with said pseudo noise signal PN(t). Said PN modulated reference signal $s_R(t)$ can also be transmitted through a different transponder of the satellite.

The characteristics of said communication channel may be group delay and amplitude response.

The above objects and other objects are also achieved by an apparatus for determining characteristics of components of a communication channel which is designed for transmitting a payload signal at a predetermined level, comprising first pseudo noise signal generating means for generating a pseudo noise signal PN(t); first modulating means for

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modulating a clean carrier signal f(t) with said first pseudo noise signal PN(t) to generate a PN modulated clean carrier signal s(t); transmitting means for transmitting said PN modulated clean carrier signal s(t) through said communication channel at a level below the level of said payload signal; receiving means for receiving a receive signal s'(t) corresponding to said PN modulated clean carrier signal s(t) after having traveled through said communication channel; and first correlating means for correlating said receive signal s'(t) with said pseudo noise signal PN(t) to generate a recovered carrier signal f'(t).

Advantageously, the level of said PN modulated clean carrier signal s(t) is at least 15 dB, preferably 25 dB or more below the level of said payload signal.

In a further embodiment, said first pseudo noise signal generating means is a feed back shift register.

A chiprate of said first pseudo noise signal PN(t) is less than 5 MChip/s preferably less than or equal to 2,5 MChip/s.

In a further embodiment, the above apparatus comprises first delaying means for delaying said first pseudo noise signal PN(t).

To obtain a reference, the above apparatus further comprises second pseudo noise generating means for generating a second pseudo noise signal $PN_R(t)$; second modulating means for modulating a reference carrier signal $f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a PN modulated reference carrier signal $s_R(t)$; transmitting means for transmitting said PN modulated reference carrier signal $s_R(t)$ through said communication channel at a

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level below the level of said payload signal; receiving means for receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through said communication channel; and second correlating means for correlating said reference receive signal $s_R'(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a recovered reference carrier signal $f_R'(t)$.

Advantageously, the level of said PN modulated reference carrier signal s(t) is at least 15 dB, preferably 25 dB or more below the level of said payload signal.

In a further embodiment, said second pseudo noise signal generating means is a feed back shift register.

In a further embodiment, the above apparatus further comprises second delaying means for delaying said second pseudo noise signal $PN_R(t)$.

In summary, for determining characteristics of components of a communication channel, for example of a transponder in a communication satellite, a clean carrier signal f(t) is modulated with a pseudo noise signal PN(t) and transmitted through the communication channel at a level below the level of a payload signal which is transmitted via the communication channel simultaneously. The received signal s'(t) is correlated with the same pseudo noise signal PN(t) to obtain a recovered carrier signal f'(t). The clean carrier signal f(t) and the recovered carrier signal f'(t) are used together to determine the desired characteristics. Since the PN modulated clean carrier signal s(t) is transmitted at a low level, it is possible to perform measurements without switching off the payload signal.

The most important advantage of the method and the apparatus according to the invention is of course that the payload signal does not have to be switched off for performing the measurements. This limits considerably the downtime required for maintenance and verification of the communication channel, and thus increases availability of services.

Another very important advantage is the fact that with this method and apparatus, it is possible to measure characteristics of components of the communication channel under realistic conditions. For example, in a satellite transponder the IMUX and OMUX filters are waveguide filters and the characteristics of these filters are changing with the temperature. Normally, the filters are not uniformly heated during operation but are heated depending on the payload signal. When the payload signal is switched off the temperature distribution changes compared to normal operation even if the test signals provide a certain power for heating the filters. Thus, with conventional methods characteristics cannot be determined under conditions present in the communication channel under load. In addition, in the proposed method the spectral power density of the measurement signal is considerably lower than the spectral power density of the payload signal, so that it is possible to characterise the behaviour of the communications channel under the most realistic circumstances.

A further advantage of the invention is that in the case of a satellite communication channel the conversion frequency of the uplink/downlink can be measured without interruption of the payload signal and simultaneously with the other measurements.

In the following an embodiment of the invention will be described in greater detail and with reference to the drawings.

Fig. 1 shows a schematic diagram of a transponder of a communication satellite;

Fig. 2 shows a schematic diagram of a first embodiment of an apparatus according to the invention;

Fig. 3a and 3b show diagrams representing measurement result;

Fig. 4 shows a schematic diagram of a second embodiment of an apparatus according to the invention.

For the purpose of describing an embodiment of the invention, Fig. 1 shows the components of a transponder in a communication satellite as an example for a communication channel.

A transponder of a communication satellite comprises a receiving antenna 1 for receiving an uplink signal send from a ground station (not shown). An output signal of said receiving antenna 1 is fed to an input demultiplexer (IMUX) 3 after frequency conversion in frequency converter 2. Said input demultiplexer 3 comprises several first filters 4-1 to 4-n for separating individual signals within the signal from the antenna. Typically, one filter is provided for each signal to be separated from the other signals received via said receiving antenna 1 and corresponds to a communication channel. The n output signals of said input demultiplexer 3 are fed to a corresponding number of high power amplifiers 5-1 to 5-n in each of which a traveling wave tube (TWT) is employed for amplifying the output signals of said input demultiplexer 3. As each of said high power amplifiers is normally operated in its saturation point, multiple signals would create intermodulation products and distortion of the signals. The amplifier output signals are passed through second filters 6-1 to 6-n which are part of an output multiplexer (OMUX) 7 combining the n amplifier output signals. The output signal of said output multiplexer 7 is fed to a transmitting antenna 8 for being transmitted to the desired area on the ground.

Since the filters provided in the input demultiplexer (IMUX) 3 and the output multiplexer (OMUX) 7 have a strong influence on the performance of the transponder, the method according to the invention will be explained in following with respect to measuring two specific characteristics, namely amplitude response and group delay, of these components of the transponder communication channels, the method of the invention being especially suitable for this application. However, the same or other characteristics of other components of the communication channel can be determined by means of the method and the apparatus according to the invention.

According to the invention, in a ground station as shown in Fig. 2, a pseudo noise signal PN(t) is generated by means of a pseudo noise signal generator 9, for example, a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored. The pseudo noise signal PN(t) has a very sharp autocorrelation function at zero delay. This allows to determine the time delay between the locally generated pseudo noise signal PN(t) and a received signal which is delayed due to the propagation time. A clean carrier signal f(t) having a variable frequency, which is changed as explained further below, is modulated with said pseudo noise signal PN(t) by means of a first multiplier 10 to form a PN modulated clean carrier signal s(t) = PN(t) x f(t). The chiprate of the pseudo noise signal PN(t), which determines the bandwidth of this signal, is chosen such the bandwidth of the PN modulated clean carrier signal s(t) is narrow in comparison with the expected peaks in group delay of the communication channel. Typically, the chiprate of the pseudo noise signal may be chosen less than 5 MChip/s.

The PN modulated clean carrier signal s(t) is fed to an upconverter 11 and via a high power amplifier 12 to an antenna 13 which transmits the PN modulated clean carrier signal s(t) to the transponder of the communication satellite under test. However, from the viewpoint of a user transmitting a payload signal to the satellite, the transponder remains usable during the test and can be continuously supplied with a payload signal.

According to the invention, the level of the transmitted PN modulated clean carrier signal s(t) is sufficiently below the level of the payload signal, for example about 15 to 25 dB or more, such that the payload signal is not notably deteriorated. For this reason, the PN modulated clean carrier signal s(t) can be transmitted while the communication channel is in use, i.e. simultaneously with a payload signal being transmitted to the transponder of the satellite from the same or from another ground station.

The frequency of the clean carrier signal f(t) is changed such that it sweeps from the lowest to the highest frequency of the pass band of the filters in the satellite transponder, or any other component of a general communication channel under test. The PN modulated clean carrier signal s(t) has a narrow bandwidth due to the pseudo noise signal PN(t) such that amplitude response and group delay of the communication channel can be determined at selected discrete frequencies, as will be described in the following.

In the embodiment, antenna 13 is also used to receive the signal re-transmitted by the transponder of the satellite, in other words the signal which has traveled through the communication channel. The output signal of antenna 13 is passed through a downconverter 14 to obtain a receive signal s'(t) which is fed to a second multiplier 15 receiving also the same but delayed pseudo noise signal PN(t). The delay is generated by delaying means 16 which are set such that the output of the second multiplier 15 becomes maximal. Thereby, the receive signal s'(t) is multiplied, in other words correlated with the very same pseudo noise signal PN(t) which has been used for generating the PN modulated clean carrier signal s(t) and a recovered carrier signal f'(t) is obtained which is only delayed and attenuated in comparison with the clean carrier signal f(t). Thus, the amplitude response, which corresponds to the attenuation of the recovered carrier signal f'(t), and the group delay, which corresponds to the delay of the recovered carrier signal f'(t), of the transponder of the satellite, as an example of a general communication channel, can easily be determined. The runtime of a narrowband signal at its center frequency corresponds to the group delay of the filters if the phase can be linearly approximated in the signal bandwidth. The chiprate of the PN signal is determined accordingly.

As far as communication satellites are concerned, it is sufficient to determine the amplitude response and group delay over the pass band of a transponder only relative to the amplitude response and group delay at the center frequency of the pass band. Therefore, it is sufficient to delay the pseudo noise signal PN(t) such that the amplitude of the recovered carrier signal f'(t) becomes maximal and to subtract the amplitude and the delay at the center frequency from the amplitude and the delay at any other frequency in the pass band, respectively.

Fig. 3a and 3b show typical measurement result for amplitude response (Fig. 3a) and group delay (Fig.3b) as obtained by the method according to the invention.

In the case of a satellite communication channel, i.e. a transponder, it should be noted that, during measurements, due to the movements of the satellite the distance to the satellite can change. Also, during measurements, due to atmospherical effects the attenuation of the path loss between the ground station and the satellite can change. Since in the above embodiment the amplitude response and the group delay is determined by subtracting the amplitude response and the group delay at the center frequency from the respective values at other discrete frequencies, an error might occur due to the before mentioned satellite movements and atmospherical effects or other influences.

As shown in Fig. 4, an reference signal $s_R(t)$can be used to compensate the before mentioned measurement error. In Fig. 4 the same reference signs are used for those parts already described above and reference is made to the above description of these parts. The reference signal $s_R(t)$ is generated by means of a third multiplier 18 which receives a second pseudo noise signal $PN_R(t)$, which is not correlated with the first pseudo noise signal PN(t) and which is generated by a second pseudo noise generator 17, and a reference carrier signal $f_R(t)$ which may be located at a fixed frequency somewhere within the pass band of the same transponder or in the pass band of another transponder on the same satellite having a different center frequency. Like in the above embodiment, a PN modulated reference carrier signal $s_R(t)$ is transmitted to the satellite and the reference receive signal $s_R'(t)$ is multiplied with the second pseudo noise signal $PN_R(T)$ to obtain the recovered reference signal $f_R'(t)$. While the measurement signal is swept in frequency over the transponder pass band, the frequency of the reference carrier signal $f_R(t)$ remains at a fixed frequency. Therefore, a corrected amplitude response and group delay of the communications channel can be obtained by subtracting the values of the reference signal from the values of the measurement signals at the respective time.

A variation of the described measuring the group delay consists of measuring the phase of the reconstructed carrier of the PN modulated signal at a specified frequency very close to the first frequency, it is possible to approximate the group delay at the frequency located in the middle of both measurement frequencies by calculating the phase difference and dividing by the frequency difference.

Only pseudo noise signals have been discussed above because these signals can be generated comparatively easily. However, true noise signals can be used in the method and the apparatus according to the invention. Properties of true and pseudo noise signals are well known to those skilled in the art and are described, for example in Bernard Sklar, "Digital Communications - Fundamentals and Applications", Prentice Hall, 1988.

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NEW CLAIMS

1. Method for determining characteristics of components of a communication channel which is designed for transmitting a payload signal at a predetermined level, comprising:

   - generating a first pseudo noise signal PN(t);
   - modulating a clean carrier signal f(t) with said first pseudo noise signal PN(t) to generate a PN modulated clean carrier signal s(t);
   - transmitting said PN modulated clean carrier signal s(t) through said communication channel at a level below the level of said payload signal;
   - receiving a receive signal s'(t) corresponding to said PN modulated clean carrier signal s(t) after having traveled through said communication channel;
   - correlating said receive signal s'(t) with said first pseudo noise signal PN(t) to generate a recovered carrier signal f'(t); and
   - determining characteristics of components of the communication channel on the basis of a comparison of said clean carrier signal f(t) and said recovered carrier signal f'(t).

2. Method according to claim 1, wherein the level of said PN modulated clean carrier signal s(t) is at least 15 dB below the level of said payload signal.

3. Method according to claim 2, wherein the level of said PN modulated clean carrier signal s(t) is at least 25 dB below the level of said payload signal.

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4. Method according to any one of claims 1 to 3, wherein said first pseudo noise signal PN(t) is a binary pseudo noise sequence.

5. Method according to claim 4, wherein said binary pseudo noise sequence is generated by means of a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.

6. Method according to any one of claims 1 to 5, wherein a chiprate of said first pseudo noise signal PN(t) is less than 5 Mchip/s.

7. Method according to claim 6, wherein a chiprate of said first pseudo noise signal PN(t) is less than or equal to 2,5 Mchip/s.

8. Method according to any one of claims 1 to 7, wherein said correlating of said receive signal s'(t) and said first pseudo noise signal PN(t) is achieved by delaying said first pseudo noise signal PN(t) and multiplying the delayed first pseudo noise signal PN(t) and said receive signal s'(t).

9. Method according to any one of claims 1 to 8, further comprising:

- generating a second pseudo noise signal $PN_R(t)$;
- modulating a reference carrier signal $f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a PN modulated reference carrier signal $s_R(t)$;
- transmitting said PN modulated reference carrier signal $s_R(t)$ through said communication channel at a level below the level of said payload signal;
- receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through

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said communication channel;

- correlating said reference receive signal $s_R'(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a recovered reference carrier signal $f_R'(t)$; and
- determining characteristics of components of the communication channel also on the basis of a comparison of said reference carrier signal $f_R(t)$ and said recovered carrier signal $f_R'(t)$.

10. Method according to claim 9, wherein the level of said PN modulated reference carrier signal $s_R(t)$ is at least 15 dB below the level of said payload signal.

11. Method according to claim 10, wherein the level of said PN modulated reference carrier signal $s_R(t)$ is at least 25 dB below the level of said payload signal.

12. Method according to any one of claims 9 to 11, wherein said second pseudo noise signal $PN_R(t)$ is a binary pseudo noise sequence.

13. Method according to claim 12, wherein said binary pseudo noise sequence is generated by means of a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.

14. Method according to any one of claims 9 to 13, wherein said correlating of said reference receive signal $s_R'(t)$ and said second pseudo noise signal $PN_R(t)$ is achieved by delaying said second pseudo noise signal $PN_R(t)$ and multiplying the delayed second pseudo noise signal $PN_R(t)$ and said reference receive signal $s_R'(t)$.

15. Method according to any one of claims 1 to 14, wherein said communication channel is a transponder of a communication satellite.

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16. Method according to claims 14 and 15, wherein said PN modulated reference signal $s_R(t)$ is transmitted through the same transponder of the satellite and said second pseudo noise signal $PN_R(t)$ not correlated with said pseudo noise signal PN(t).

17. Method according to claims 14 and 15, wherein said PN modulated reference signal $s_R(t)$ is transmitted through a different transponder of the satellite.

18. Method according to any one of claims 1 to 17, wherein one of the characteristics of said communication channel is group delay and/or amplitude response.

19. Apparatus for determining characteristics of components of a communication channel which is designed for transmitting a payload signal at a predetermined level, comprising:

- first pseudo noise signal generating means (9) for generating a pseudo noise signal PN(t);
- first modulating means (10) for modulating a clean carrier signal f(t) with said first pseudo noise signal PN(t) to generate a PN modulated clean carrier signal s(t);
- transmitting means (11, 12, 13) for transmitting said PN modulated clean carrier signal s(t) through said communication channel at a level below the level of said payload signal;
- receiving means (13, 14) for receiving a receive signal s'(t) corresponding to said PN modulated clean carrier signal s(t) after having traveled through said communication channel; and
- first correlating means (14) for correlating said receive signal s'(t) with said pseudo noise signal PN(t) to generate a recovered carrier signal f'(t).

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20. Apparatus according to claim 19, wherein the level of said PN modulated clean carrier signal s(t) is at least 15 dB below the level of said payload signal.

21. Apparatus according to claim 20, wherein the level of said PN modulated clean carrier signal s(t) is at least 25 dB below the level of said payload signal.

22. Apparatus according to any one of claims 19 to 21, wherein said first pseudo noise signal generating means (9) is a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.

23. Apparatus according to any one of claims 19 to 22, wherein a chiprate of said first pseudo noise signal PN(t) is less than 5 Mchip/s.

24. Apparatus according to claim 23, wherein a chiprate of said first pseudo noise signal PN(t) is less than or equal to 2,5 Mchip/s.

25. Apparatus according to any one of claims 19 to 24, further comprising first delaying means (16) for delaying said first pseudo noise signal PN(t)..

26. Apparatus according to any one of claims 19 to 25, further comprising:

- second pseudo noise generating means (17) for generating a second pseudo noise signal $PN_R(t)$;
- second modulating means (18) for modulating a reference carrier signal $f_R(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a PN modulated reference carrier signal $s_R(t)$;
- transmitting means (11, 12, 13) for transmitting said PN modulated reference carrier signal $s_R(t)$

AMENDED SHEET

through said communication channel at a level below the level of said payload signal;

- receiving means (13, 14) for receiving a reference receive signal $s_R'(t)$ corresponding to said PN modulated reference carrier signal $s_R(t)$ after having traveled through said communication channel; and
- second correlating means (20) for correlating said reference receive signal $s_R'(t)$ with said second pseudo noise signal $PN_R(t)$ to generate a recovered reference carrier signal $f_R'(t)$.

27. Apparatus according to claim 26, wherein the level of said PN modulated reference carrier signal s(t) is at least 15 dB below the level of said payload signal.

28. Apparatus according to claim 27, wherein the level of said PN modulated reference carrier signal s(t) is at least 25 dB below the level of said payload signal.

29. Apparatus according to any one of claims 26 to 28, wherein said second pseudo noise signal generating means (9) is a feed back shift register or a memory device in which a sequence of values of a pseudo noise signal is stored.

30. Apparatus according to any one of claims 24 to 29, further comprising second delaying means (19) for delaying said second pseudo noise signal $PN_R(t)$.

31. Apparatus according to any one of claims 19 to 30, wherein one of the characteristics of said communication channel is group delay and/or amplitude response.

AMENDED SHEET

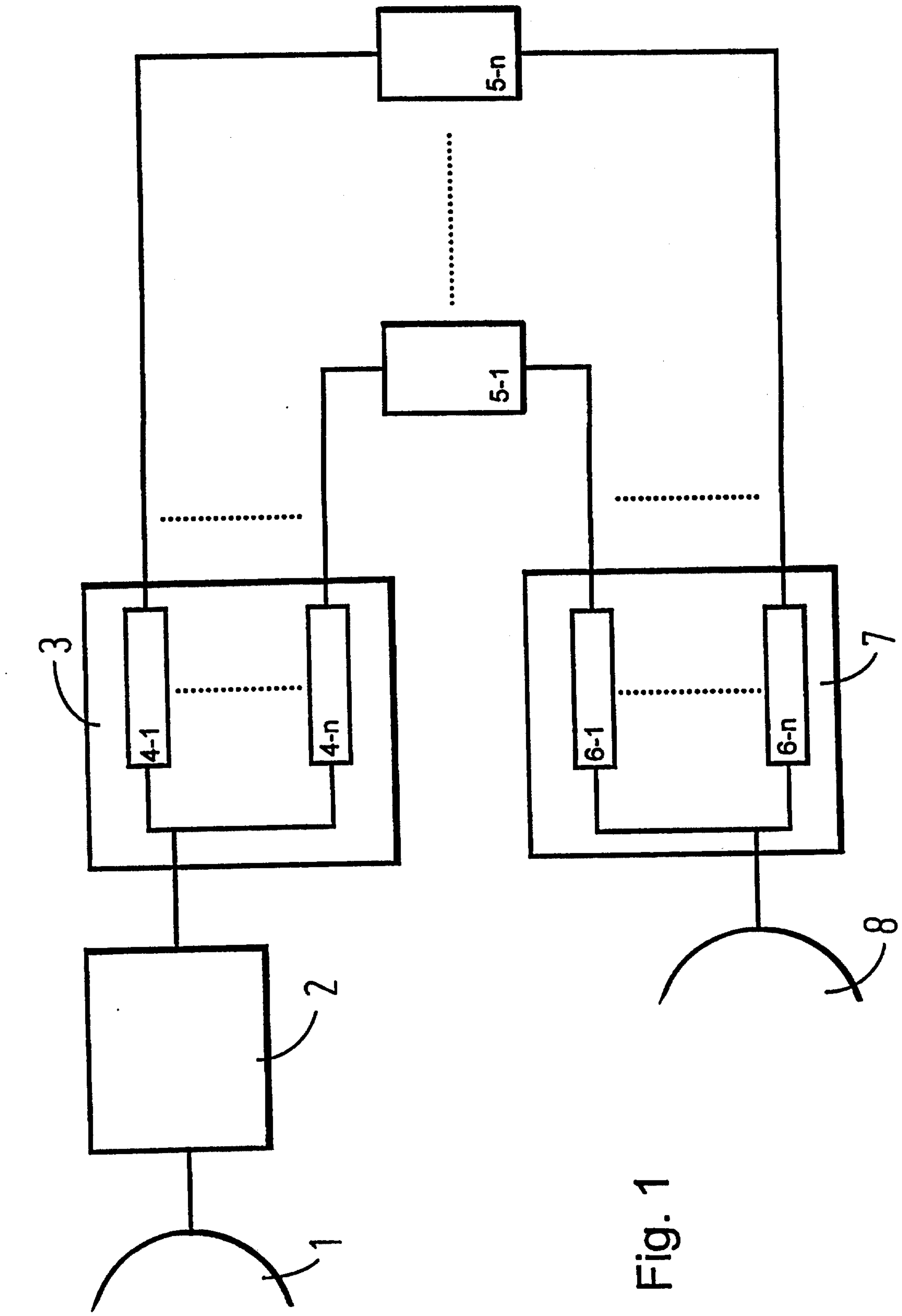


Fig. 1

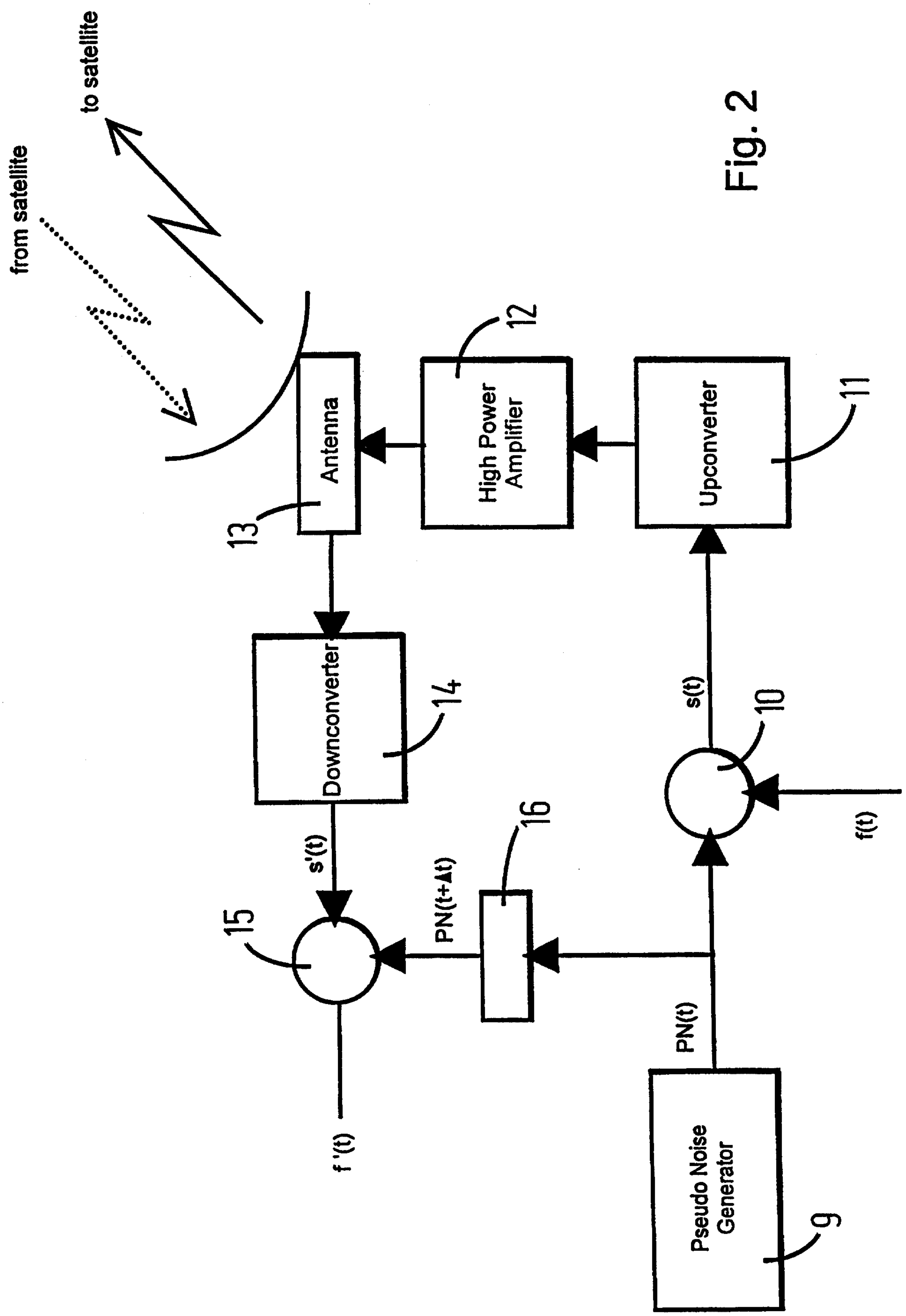

from satellite
to satellite
Antenna
High Power Amplifier
Upconverter
Downconverter
Pseudo Noise Generator
9
10
11
12
13
14
15
16
s(t)
s'(t)
f(t)
f '(t)
PN(t)
PN(t+Δt)

Fig. 2

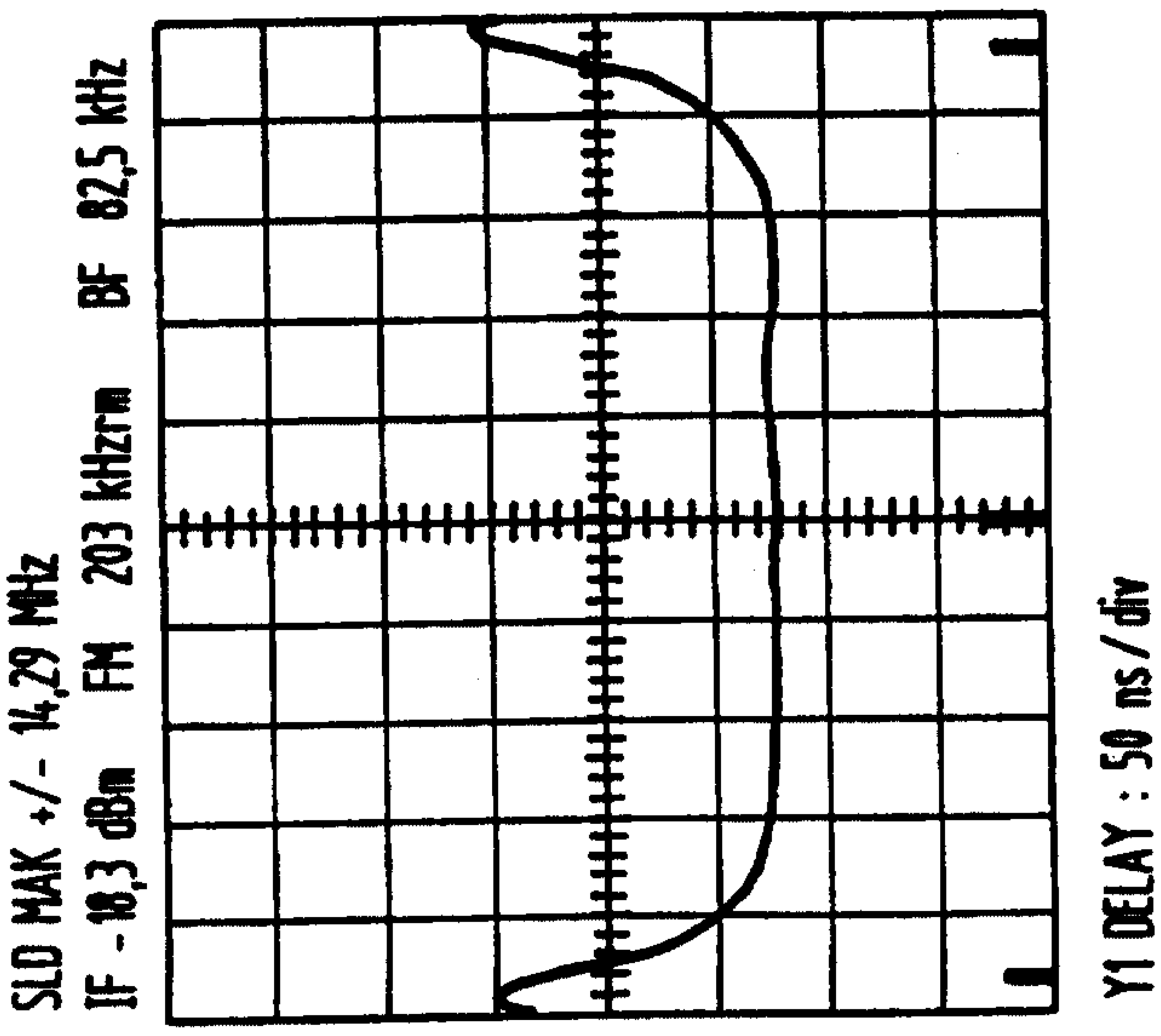

SLD MAK +/- 14,29 MHz
IF -18,3 dBm FM 203 kHzrm BF 82,5 kHz
Y1 DELAY : 50 ns/div

Fig. 3b

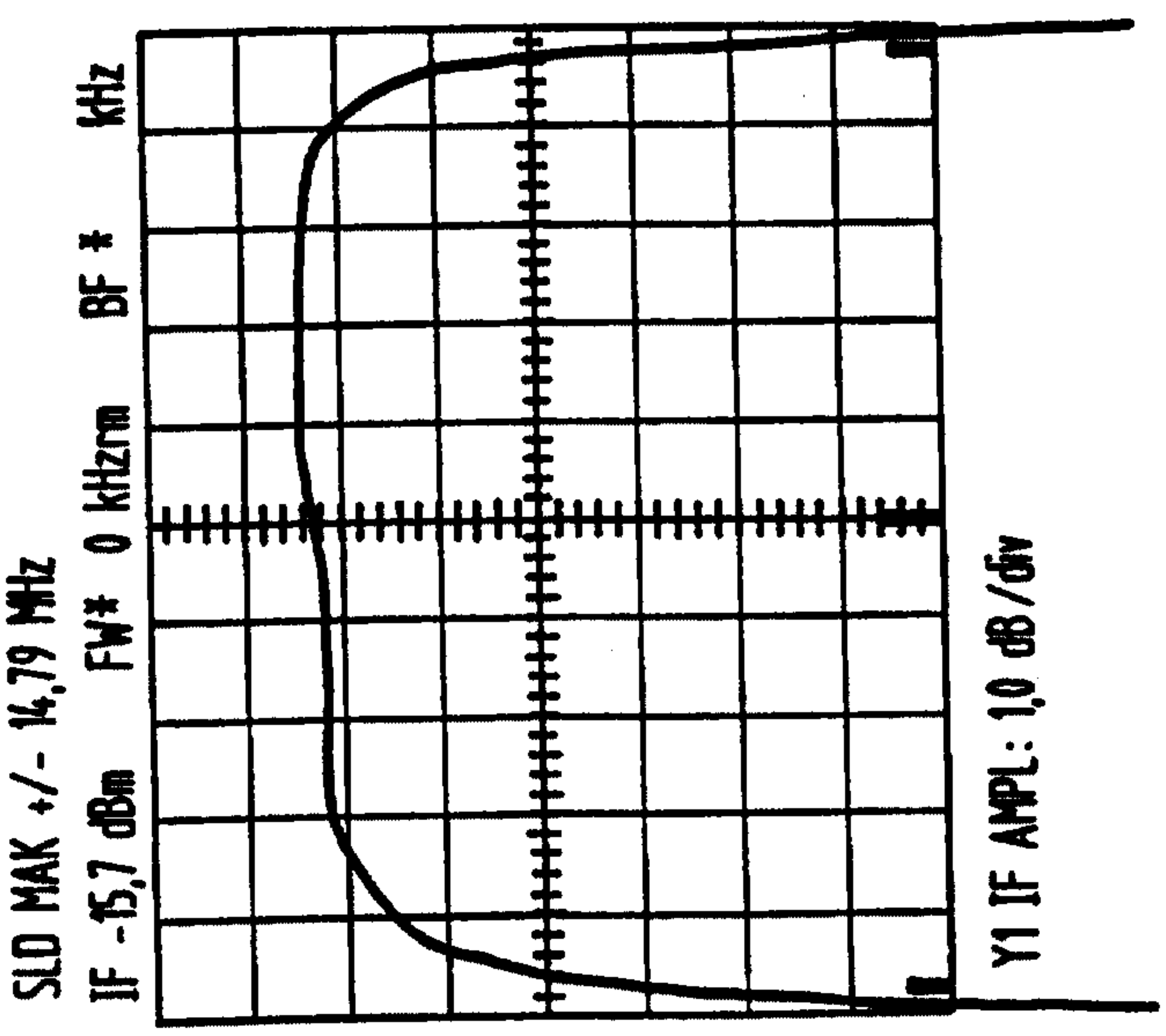

SLD MAK +/- 14,79 MHz
IF -15,7 dBm FW* 0 kHzrm BF * kHz
Y1 IF AMPL: 1,0 dB/div

Fig. 3a

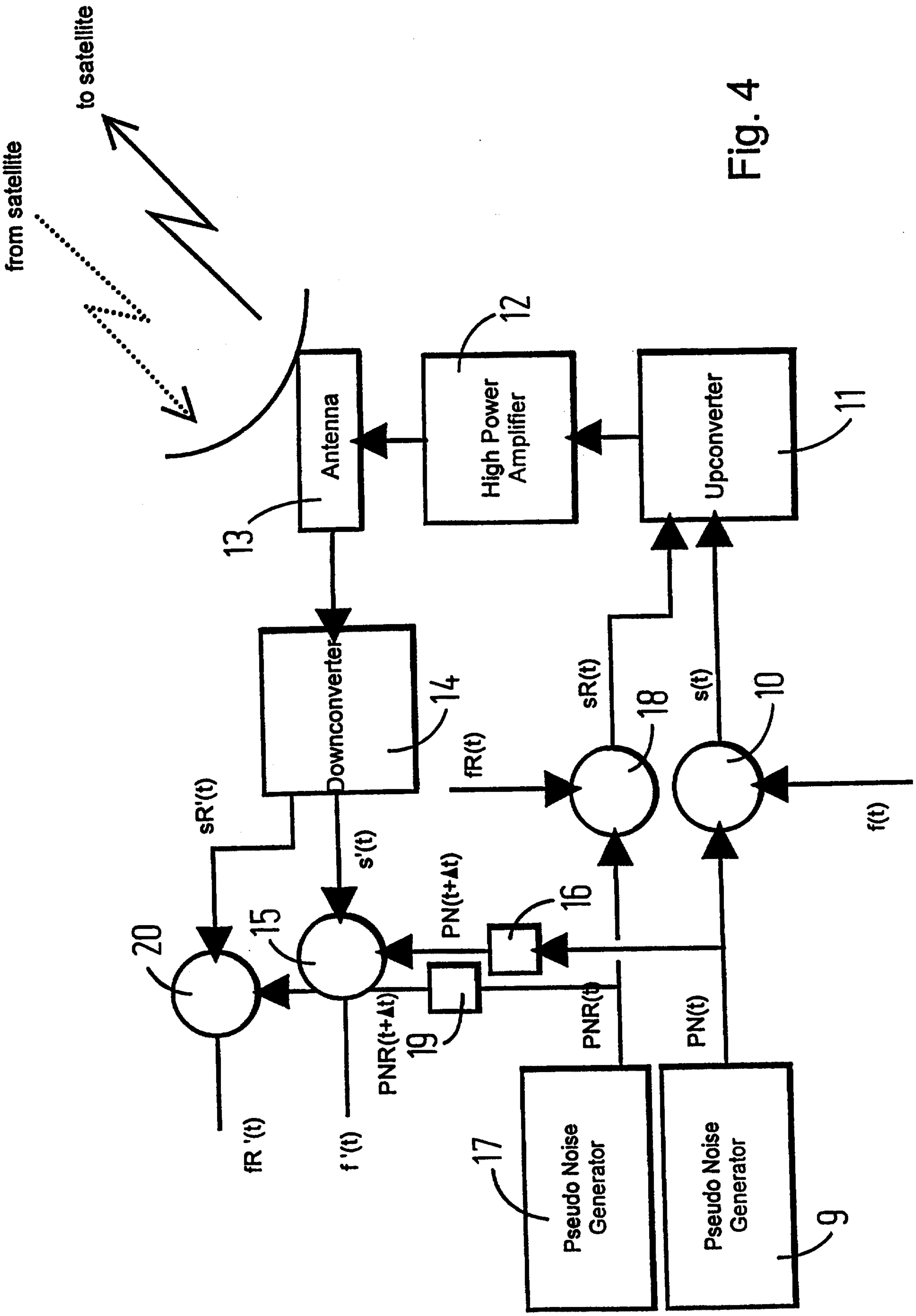
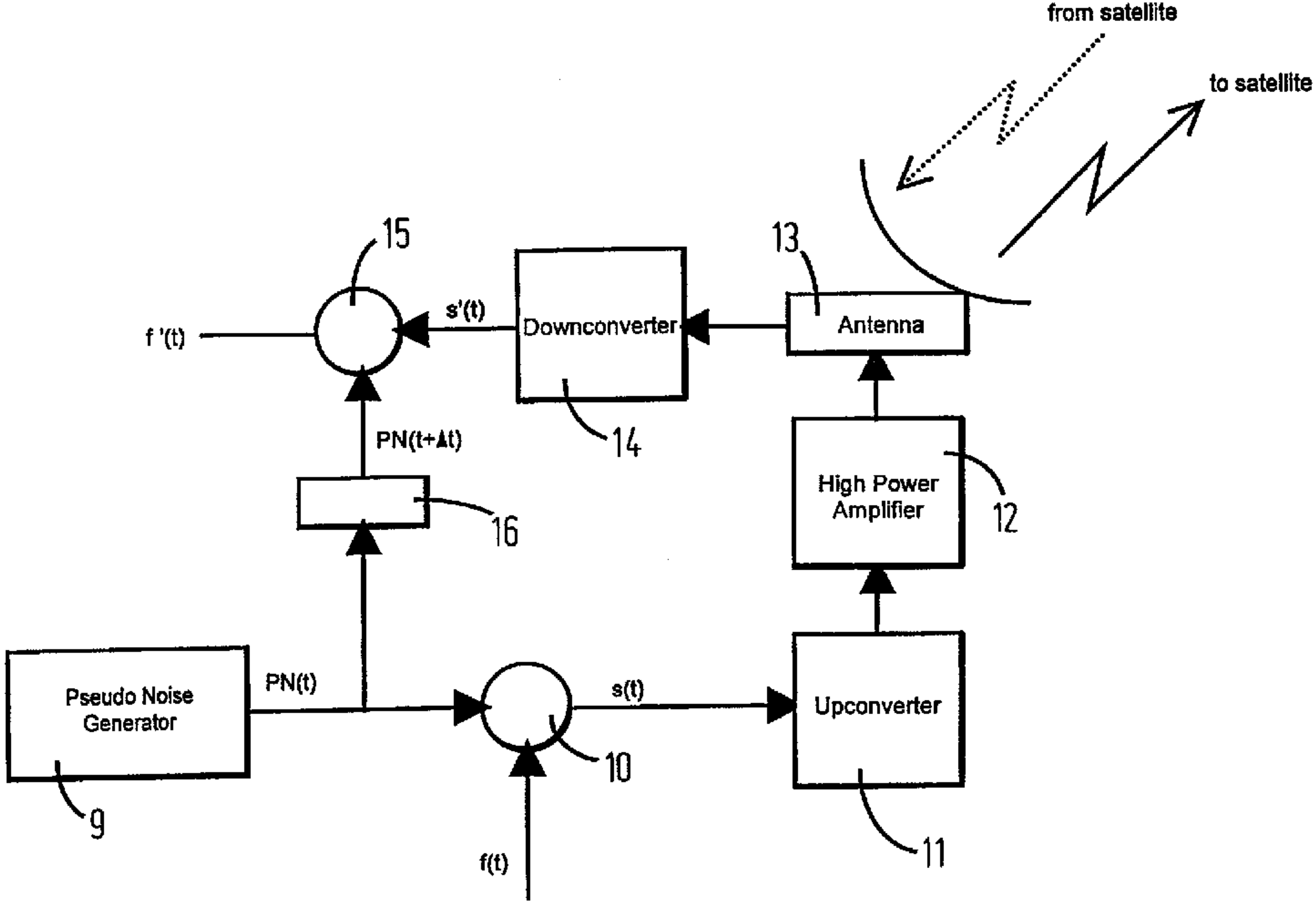

from satellite
to satellite
Antenna
High Power Amplifier
Upconverter
Downconverter
Pseudo Noise Generator
Pseudo Noise Generator
sR'(t)
s'(t)
sR(t)
s(t)
fR(t)
f(t)
PN(t+Δt)
PNR(t+Δt)
PNR(t)
PN(t)
fR '(t)
f '(t)
9
10
11
12
13
14
15
16
17
18
19
20

Fig. 4



from satellite
to satellite
15
13
s'(t)
f '(t)
Downconverter
Antenna
PN(t+Δt)
14
High Power
Amplifier
12
16
Pseudo Noise
Generator
PN(t)
s(t)
Upconverter
10
9
11
f(t)