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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04B 7/204

A1

(11) International Publication Number: WO 98/10535

(43) International Publication Date: 12 March 1998 (12.03.98)

(21) International Application Number: PCT/EP96/03924

(22) International Filing Date: 6 September 1996 (06.09.96)

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(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: WIRELESS COMMUNICATIONS SYSTEM USING BEAM DIRECTION MULTIPLEXING

(57) Abstract

In wireless multipoint communications systems operating at high frequencies and with large bandwidths highly directive antennas are needed in order to provide an acceptable link budget. This contradicts the requirement that the individual stations may be spread over a large angular area. The problem is solved by using a master slave arrangement where the master is equipped with a steerable beam antenna that scans each slave station, exchanging data when pointing to it. In multipoint communications systems with link delays in the order of magnitude of packet lengths there is the problem that if a station sends, the other stations have no chance of knowing it before the link delay between the sending station and them is over. Thus, when another station sends within that interval, a collision occurs. The problem is solved by each station broadcasting its subsequent transfer requirements and the system thus establishing an overall transmission schedule. In a satellite context using LEOs the satellite density for sufficient coverage must be dimensioned for point most distant from the common intersection point. This leads to a satellite surplus close to the intersection point. This can be used to deactivate surplus satellites and thus to save onboard energy. In such satellite systems the individual ground stations all have a different doppler shift that depends on their relative position to the satellite. As for proper operation of such networks the angular position is known anyway (for pointing the beam) it can be used to determine slant speed and consequently the doppler shift.

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Wireless communications system using beam direction multiplexing

1. Description of the prior art

The invention is concerned with wireless communications systems, particularly digital communications networks.

Wireless communications systems have been in use for a long time for a variety of uses, principally for two classes of applications: fixed communications links and mobile communications systems.

Fixed links come in principally two flavours: terrestrial radio links and satellite radio links. Both serve as a low cost replacement for cables.

A typical property of such systems is the fact that they normally are almost literally a cable replacement: classical terrestrial radio links normally link two points.

Satellite systems for fixed links principally come in two flavours: systems for linking ground stations that are at a large distance from each other and systems that are relatively close to each other.

The former corresponds to the classical configuration: a satellite with a small, wide aperture antenna and ground stations with large high gain antennas. Due to the large antenna required such systems are relatively expensive.

The latter corresponds to a newer scheme with satellites using large, "spot beam" antennas. This allows relatively small ground stations which, however, have to be relatively close to each other.

There is also the possibility to equip a satellite with a number of spot beam antennas to illuminate specific areas which are distant from each other. However, this makes the satellite much more complex and heavy, and consequently, expensive. Furthermore, it only allows to illuminate specific predefined areas.

In the context of mobile communications systems, so far only terrestrial systems in the form of cellular telephones and packet radio systems have been successful. Satellite systems, due to the fact that relatively large antennas are needed for useful bandwidths, only play a marginal role, particularly in the marine communications field.

However, all conventional radio communications systems suffer from the problem that available bandwidth, operating frequency, necessary antenna area and antenna aperture are linked in a very disadvantageous way. If a high transmission bandwidth is required, a high operating frequency is required. In order to achieve a sufficient link budget, a certain minimum antenna gain and consequently effective antenna area is required. This results in a narrow antenna aperture, in fact, the antenna aperture for a certain link budget, antenna aperture decreases with rising frequency. This is the reason why mobile communications systems, where omnidirectional aperture is required at least for the central hub station, use relatively low frequencies (generally below 2 GHz) and only operate over short distances (the cellular radio approach).

In satellite systems, distances to be covered are much longer than in the case of terrestrial systems. This means that a satisfactory link budget for small ground stations is very difficult to achieve which explains why so far satellite systems only play a marginal role in mobile communications.

In the case of TDMA systems, in which several stations use the same channel using packetized transmission schemes, there is also the problem of transmission delays. Even if each station is able to receive each other station on the channel, there may be collisions if two stations try to transmit at the same time. This is due to the fact that it takes the transmission delay time between the two stations in order that any of the two stations is able to detect that the other is transmitting. If both start transmitting at the same time within the transmission delay period they have no possibility to know that another station is transmitting as well and a collision will ensue.

The above effect is particularly serious serious in satellite communications systems, where it practically rules out the use such CD/CSMA systems. They therefore normally use variations of the ALOHA approach, which is, however, rather inefficient.

However, the problem happens in terrestrial systems as well if transmission speeds are sufficiently high. In a system using 100 Mbit/s and a packet length of 256 bytes (2048 bits) a packet has a duration of about 20 microseconds. If two stations in a multi - station single channel system are 10 km distant from each other this results in a one way propagation delay of 30 microseconds, which is longer than the packet. It is evident from this example that CD/CSMA won't work anymore in such a system and the only choice known in the art would be some kind of ALOHA with all its efficiency problems.

2. Summary of the invention

It is an object of the invention to provide a communications network allowing the use of small, inexpensive end user stations.

It is a further object of the invention to achieve this using simple, lightweight, low powered base stations having only a small number of high gain antennas used to accommodate even a large number of users.

It is an even further object of the invention to provide an optimum synchronization scheme between many stations in a network, operating by taking into account the individually different link delays, even when these delays are constantly changing, and thus optimizing channel usage in a way that packets may be packed very densely without any collisions occurring.

It is an even further object of the invention to provide a way to build radio based networks with the same flexibility as ALOHA but with a much better channel usage than ALOHA systems.

It is an even further object of the invention to provide a way of synchronizing transmission in a non - collision way for multi - station radio networks even if link delays are large, as in the case of satellite based networks.

It is an even further objective to meet all the above objectives while providing a communications data rate for each user which is sufficiently high to provide services requiring high data rates like multimedia.

It is an even further object of the invention to combine all these approaches into an overall system by designing a protocol that makes optimum use of each of them.

It is an even further object of the invention, particularly in the case of satellite systems, to provide automatic compensation of the Doppler effect which is a result of the proper motion of satellites as well as the rotation of the earth and which are different according to the direction in which a end user station is positioned with respect to the respective satellite.

It is an even further object of the invention to provide such a login system providing an approximate initial bearing at the central station and at the end user station, then carry out an exact time synchronization including an accurate round trip delay measurement and finally carry out the insertion of the new active station into the station scanning cycle used for central station / end user station communication.

In case of LEO and MEO systems it is a further object of the invention to provide - if the number of satellites cannot be reduced to the possible minimum required by topological considerations because of the laws of celestial mechanics - a satellite mass savings using said difference.

In order to provide large bandwidths it is necessary to have a sufficiently low link loss. Given certain practical limits of antenna area on both ends of the link and a certain link length, the only variable available is frequency. It is well known from classic electromagnetic theory that under conditions of constant effective antenna area on both sides of a link the loss as seen between the antenna terminals is inversely proportional to the square of the frequency used.

However, it is also well known that antenna beam width of an antenna of a given area is also inversely proportional to the operating frequency. Thus, although it is not much of a problem to provide an adequately low link loss, the result is that the area being illuminated by said antenna is much smaller than the area to be served by said central station station.

To solve this problem the following scenario may be considered: In a practical packet system the central station has packets to transfer to the individual stations and the individual stations packets to be transferred to the central station. Considering first the direction from the base station to the individual stations, it becomes apparent that in fact a connection to a particular station is only required when a packet has to be transferred thereto. Otherwise a connection to this particular station is not required. Departing from this consideration, an approach may be devised in which the antenna at the central station is an antenna the beam direction of which may be steered, e. g. a phased array antenna. Further assuming that the central station knows all the directions towards the end user stations to be served, the central station may point its beam towards a station to which it has a packet to transfer, emit its packet, subsequently direct its beam towards the next station, emit the next packet, and so on until all packets have been delivered, and then start the whole process all over again in the next cycle. In this way the beam of the central station antenna hops from one station to the next, the central station may service an area as large as desired, the service area size being completely independent from the beam aperture of the antenna, although only one antenna for transmission is used.

Analogously, when transferring packets from the end user stations to the central station a similar approach may be used. However, in order to point its antenna to a particular station to receive a packet sent by it, the central station has to know the exact time of arrival of said packet from said station. In order to do so, the path delay from the end user station towards the central station has to be known. Furthermore, the time bases of the end user station and the central station must be synchronized.

If the communications system works with fixed time slots, not much more is required: as soon as a user station is logged into the communications queue, the respective reception and transmission times stay the same as long as the individual communications session takes. However, this is rather wasteful: it is well known that the requirements for data transmission capacity vary largely within almost any practical communications session. In a fixed time slot, however, a certain data transfer capacity is assigned, which, in practice, isn't fully used most of the time.

If this should be avoided transmission capacity has to be dynamically assigned as required. Each end user station then has to indicate each time it transfers a packet whether and what size of packet it will transfer next time. It may also indicate the size of packets for a number of cycles beforehands or request not to be polled for a number of subsequent cycles, depending on the traffic situation it experiences. Provided with this information the central station sets up a scanning schedule for the next cycle and allots time slots to each of the stations with the next packets it downlinks to them, thereby also taking link delay into account.

This causes all the user stations to send their information at the correct time, so that they arrive at the central station one after the other, so that it is able point its beam at each station, one after the other, thus gathering all the upbound packets.

Synchronisation and path delay measurement in general are done in the following way: Each time the central station sends a packet to an end user station it adds the result of the last cycle time delay measurement as well as the time the packet was sent. When the user station receives this packet, it time stamps the packet with the time of arrival. Then it uses the information about time of transmission and link delay contained in said packet to calculate the time indication of the central station at the time the packet was received. It then compares this value with the time stamp it provided itself at the time of arrival of said packet, and, should there be a difference, adjusts its own time scale accordingly.

When sending a packet to the central station, the end user station provides in this packet the time when the packet was sent as well as the time it received the last packet or the time that has already passed between reception of the last packet and the transmission of the current packet. At the time this packet arrives at the central station, it is time stamped. The central station now compares this time stamp with the one of the last packet it sent to said station and determines the time difference. Then it takes the information provided by the end user station in its last packet and subtracts the time that passed between the reception of the last packet at this station and the emission of the current packet received from it. The result is the round trip delay. Dividing this by two provides link delay to this particular station. Next time a packet is sent down to said end user station this value together with the time of transmission of said packet is included in it.

The above considerations assume that at least the base station is equipped with transmission and reception facilities that are independent from each other, i. e. the ransmitter as well as the receiver have either separate, independently steerable antennas and operate in different frequency bands. They may also operate with a combined antenna system, which is actually two antenna systems integrated into one and with independently steerable beams for reception and transmission.

In the case of short distances and consequently short propagation delays between base station and user station (e. g. terrestrial systems) a complete communications cycle, that is, a cycle in which each user station exchanges data with the base station, may be subdivided in one section of "user stations send, base station receives" and a subsequent section "base station sends, user stations receive" or vice versa, the whole being carried out in the same frequency band. There has to be a guard time between the two sections of at least one propagation delay towards the user station that sends its data last in the "user stations send, base station receives" cycle, then the "base station sends, user stations receive" cycle can start. This is required because elsewise the reception of the above last packet of the "user stations send, base station receives" cycle would be clobbered. This required guard time is only acceptably short with respect to a complete communications cycle in short range applications.

To provide an initial login several alternatives are possible. With fixed systems, in which the user station antenna is always directed towards the base station, a wide aperture antenna for login purposes at the base station will be sufficient in most cases. The gain of this antenna is sufficient, because the login process can be carried out with rather low bandwidths. Due to its very nature (there is no a priori knowledge of the data of stations that want to log in), it must be carried out using some kind of ALOHA approach. This is possible, because only very few data are transferred during login and the whole process only takes a short time. There are generally also not many logins per time unit to be expected.This antenna and the associated receiver has to be designed in a way that it is possible to determine the bearing of each incoming signal (e. g. a "monopulse" system).

If a user station wants to log in, it sends its identification code as well as a time stamp to the central station. The base station now requests the preparation of a time slot from the main communication unit and gets it assigned. Now the respective time slot data as well as the delay between reception of the request packet and the acknowledge packet are sent to the user station. Login communications then is terminated.

After that, the user station switches into main communications mode. It receives packets from the base station and replies with short packets at the middle of its assigned transmit time slot. The base station exactly determines the position of these packets with respect to its assigned time slots and sends the values back to the user station. The user station uses these values to calculate link delay and thus to exactly position its packets, and, as soon as the time position at the base station is correct, starts sending full length packets containing actual user information.

The approach described in the above is satifactory for terrestrial systems in which the distances covered are relatively short. In case of satellite systems, distances and link losses are much larger, and the requirements for initial angular and link delay precision are much higher. Then an alternative approach as described in the following is more suitable.

For this approach each base station carries a separate beam steerable login antenna of typically a tenth of the linear dimensions of the main communications antenna. The total area to be serviced by this antenna is subdivided into cells of the width of the beamwidth of this antenna. These cells are continuously scanned with the antenna. There is a login transceiver connected to the antenna the transmitter of which constantly sends out a signal, which normally is unmodulated as long as no login communications are carried out.

For the end user station there are two possibilities: the simpler one is that it has a conventional antenna, in which case it simply waits for a signal from the base station. The more complex one is that the ground station also has a steerable beam antenna. If such a station wants to log into the network, it also scans the sky. The entire hemispherical area then is subdivided into cells with the beamwidth of the end user steerable beam antenna. Scanning now the area beyond the grazing angle cell by cell, it stops when it finds a signal. Upon receipt of a signal from the base station both types of user stations turn their transmitter on and send their identification code plus a time stamp indicating the actual user station time cyclically for a predefined period of time. When the base station login receiver detects this signal, it logs the station identification and the time stamps. After the last identification and time stamp block has been received, the base station send a signal back. This signal contains the last time stamp received from the user station, the delay until the base station sent an answering signal, its own time stamp indicating the begin of its own transmission as well as other organizational data. Furthermore, the signal is superposed with a low intensity (ten to twenty decibles less) PN - 2 - PSK signal. The origin time stamp of the PN signal is also included in the back signal from the base station.

The data received from the base station enable the user station to coarsely determine the round trip delay towards the base station. This information is used to calculate the occurrence of the origin of the PN signal at the user station. Presetting the PN correlator with this data, the correlator is capable of quickly locking onto the PN signal. After having locked the user station replies with a signal that is also PN modulated, indicating the time difference of the origin of its own signal with respect to the origin of the signal received from the base station. It also sends the results of the coarse round trip delay measurement. Using this, the base station PN correlator quickly can lock onto the uplinked PN signal. Having locked in, an exact round trip delay value can be determined. Furthermore, by dithering beam direction, the exact beam heading to the user station is determined. Having done all this, the login unit requests putting the new active station into queue at the main antenna beam control and user access management unit. Now a time slot for transmission of the user station as well as a time slot for transmission of the base station is defined. After having received these data, the login unit downlinks them to the user access station. Then control is passed to the main communications facility at the base station.

In the general case of multi station radio networks in order to eliminate the situation of collision in a network it has to be ensured that everybody hears everybody. This can be achieved by a topology using a radio transponder in a position where all stations in the network can communicate with it directly. The transponder in fact may be transparent, that is, it transmits everything it receives in the same way, without any treatment of the data whatsoever. The stations around it thus can all hear each other by means of the base transponder. Thus, as long as link delays are negligible, collisions are effectively eliminated in a simple CSMA environment. Furthermore, all stations can transmit their traffic directly to the recipient station without any need to handle traffic using intermediate stations due to lack of a direct path. If in this case the link delay times due to large distances come into the same order of magnitude than the packet length, collisions may occur due to the "blind times" provided by the fact that, if a station sends, it takes some time until the other stations can receive the transmission. If another station happens to send within that time, a collision may occur. In order to prevent this, all stations have to be informed about the activities and intentions of all other stations in the network and adjust their transmissions accordingly. This is achieved in the following way: each station sends with each packet information about the traffic loading presently encountered. Furthermore all stations listen to their own packets back and determine the round trip delay time.

A node control station in the system collects all this information and gains an overview of of the loading distribution in the system. From this it determines which station needs what percentage of the total available transfer time and accordingly constructs a transmission sequence schedule. This transmission sequence schedule is sent to all nodes in the system together with a send time stamp. The send time stamp serves for synchronizing all nodes in the system to the time scale of the node control station.

A control cycle is a complete round of data exchange operations, in which every station in the network sends and receives data one after the other. A transmit permit is passed from one node to the next, it is passed circularly around, such a cycle constituting a data transfer cycles. The individual time slots in such a cycle are different and adjusted on command of a transmission sequence schedule instruction from the node control station. At the beginning of each control cycle a transmission sequence schedule is sent. Only and if this packet is received correctly by a node transmission is continued according to the new instructions. If the reception of said packet is incorrect, transmission is stopped until the next correctly received transmission sequence schedule packet is received. This latter property is essential to avoid that nodes send with a different time schedule which could lead to systematic packet collisions with consequential communications breakdown in the system.

If such a wireless communications network is realized using a system of orbiting satellites, clever network management with partial deactivation of satellites should also be taken into consideration.

It is well known that the power supply system constitutes a substantial part of the total mass of any satellite. A reduction in power requirement directly translates into a lighter satellite, particularly, because any energy consumed by the satellite is converted into heat by a large fraction. This heat has to be removed by a cooling system, another considerable weight factor in a satellite. If power consumption of a satellite can be reduced, the cooling system also becomes smaller.

A typical satellite is powered by solar panels and a storage accumulator bridging times during which the satellite is in the earth's shadow. It also helps in making peak power for short periods of time available to the satellite, in other words, it levels out power consumption as seen by the solar panels.

Thus, if it would be possible to power down the satellite for fractions of its orbit this would translate into a lower average power consumption with all the advantages as set out in the above.

Now, considering areas with a satellite density above minimum the question arises whether some satellites might be switched into standby mode in order to save energy while still providing the required services. A more detailed analysis shows that this is possible if satellites exist the deactivation of which leaves a network in which the distances between the remaining active satellites are smaller or equal than the maximum distance between satellites in the least dense areas that occur in the respective configuration.

There may, however, be situations in which the deactivation of such a "superfluous" satellite may be unwise because traffic loading in this area of the network is very high and the supplementary satellite helps in better distributing the traffic loading.

Another consideration takes the fact into account that in fact the surface of the earth is very different: there are large areas, especially the oceans, where traffic loading is very light and at the same time the grazing angle requirements are very relaxed because the environment is all level. In a satellite network designed for a high grazing angle more than half of the satellites may be switched into standby mode without degrading the service. As oceans constitute about two thirds of the earth's surface, the savings can be substantial.

3. Brief description of the drawings

3.1. A wireless local loop system

3.1.1. Base station

Figure 1 shows a block diagram of the login unit

Figure 2 shows the operation of the login unit

Figure 3 shows a block diagram of the operations unit

Figure 4 shows a block diagram of the input data multiplexer

Figure 5 shows a block diagram of the output data demultiplexer

Figure 6 shows a block diagram of system control

Figure 7 shows the operation of the time slot administation transmission

Figure 8 shows the operation of the time slot administation reception

Figure 9 shows the operation of the transmit / receive collision avoidance at subscriber station

Figure 10 shows the operation of dither control

Figure 11 shows a block diagram of the RF system

3.1.2. Subscriber station

Figure 12 shows a block diagram

Figure 13 shows the operation of the login unit

Figure 14 shows a block diagram of the input data multiplexer

Figure 15 shows a block diagram of the output data demultiplexer

Figure 16 shows a block diagram of system control

3.2. Satellite based subscriber access system

3.2.1. Base station

Figure 17 shows a block diagram of the login unit

Figure 18 shows the general layout of the login system

Figure 19 shows the operation of the doppler compensation in the login unit

Figure 20 shows the operation of the login unit

Figure 21 shows a block diagram of the operations unit

Figure 22 shows a block diagram of the input data multiplexer

Figure 23 shows a block diagram of the output data demultiplexer

Figure 24 shows a block diagram of system control

Figure 25 shows the operation of the time slot administation transmission

Figure 26 shows the operation of the time slot administation reception

Figure 27 shows the operation of the transmit / receive collision avoidance at subscriber station

Figure 28 shows the operation of dither control

Figure 29 shows a block diagram of the RF system

Figure 30 shows an orbital arrangement with similar orbits all intersecting in one point

Figure 31 shows an orbital arrangement with different orbits intersecting at different points

Figure 32 shows the operation of the dynamic satellite turn on and turn off process

Figure 33 shows the operations associated with the reactivation of satellites.

3.2.2. Subscriber station

Figure 34 shows a block diagram

Figure 35 shows a block diagram of the login unit

Figure 36 shows the operation of the login unit

Figure 37 shows a block diagram of the input data multiplexer

Figure 38 shows a block diagram of the output data demultiplexer

Figure 39 shows a block diagram of system control

3.3. A multistation wireless communications network

Figure 40 shows an example of a network topology

3.3.1. The end node

Figure 41 shows a block diagram

Figure 42 shows a block diagram of the input data multiplexer

Figure 43 shows a block diagram of the output data demultiplexer

Figure 44 shows a block diagram of system control

3.3.2. The transfer node

Figure 45 shows a block diagram

Figure 46 shows a block diagram of the input data multiplexer

Figure 47 shows a block diagram of the output data demultiplexer

3.3.2.1. Link set

Figure 48 shows a block diagram

Figure 49 shows a block diagram of the input data unit

Figure 50 shows a block diagram of the output data unit

Figure 51 shows a block diagram of system control

3.3.3. The star transponder

Figure 52 shows a block diagram

Figure 53 shows a block diagram of the input data multiplexer

Figure 54 shows a block diagram of the output data demultiplexer

Figure 55 shows a block diagram of the node control system

Figure 56 shows the operation of the time slot data administration as carried out by the node control system

4. Detailed description of the invention

The invention is illustrated in the following using three embodiments of rather typical applications.

The invention draws heavily on digital packet protocols and routing methods typical for digital communications systems. However, they are only dealt with as much as is necessary to render the operation of the embodiments clear and insofar as they touch the invention.

General information abot packet protocols can be found, for example, in "Computer Networks"; Andrew S. Tanenbaum;

published by Prentice Hall.

4.1. A wireless local loop system

The wireless local loop system described in the following serves to link a multitude of subscribers scattered around a central point to said central point. It is further data transparent, that is, any data fed into the subscriber line will come out in the same way at the central point, without modification. This allows the system to be used in any thinkable protocol environment, be it ISDN, ATM or anything else.

The embodiment described here uses adjusts channel capacity to actual requirements. A system that assigns a fixed channel capacity, that is fixed time slot widths, to each channel without any demand adjustment is also possible and would be simpler. It is, however, less efficient. In some applications with fixed channel width transfer protocols (e. g. ISDN) it may, however, make sense.

4.1.1. Base station

The base station - generally speaking - is made up of an operations section handling normal communications operations and a login section accepting and handling login requests of stations having been inactive so far.

4.1.1.1. Login section

The login section serves to enable subscriber stations, which have been inactive so far, to set up an active communications link to the base station. Its block diagram is shown in Figure 1.

The login section may also send out a call to a subscriber station and request a particular subscriber station to issue a login request. This is necessary if there is an incoming communications request towards a particular subscriber station (incoming call).

The bandwidths used for this are much narrower than those used in an active communications link. This poses no problem because the amounts of data to be transferred are small and communications furthermore only take place before setting up an active communications link, in other words, communications via the login system are rather rare.

The antenna system is a large aperture low gain system. Together with the associated receiver it is designed in a way that the direction of an incident signal can be determined immediately (mono pulse approach).

Transmitter and receiver are conventional, narrow band units.

The login communications unit handles login operations, accepts information received from subscriber stations, sends related reply information and communicates with system control.

Figure 2 shows the sequence of actions during a login at the base station. Explanation starts in the top left corner, where the login system waits for a login request packet. If such a packet is received, the time of reception and the angle of incidence are determined. Then the station identification code extracted from it. Using the station identification a time slot pair is requested from system control. If one is available, it is assigned. Otherwise a "no channel available" message is returned. In this latter case, a reply packet indicating non availability of a communications time slot pair is sent to the user station. Then communications is terminated.

If, however, a time slot is available, system control returns the time slot timing and duration information. This information, together with the time the request packet was received and the time the reply packet is to be sent are entered into the reply packet. This packet then is sent.

After this communications of the login section with the subscriber station is finished. All further actions are handled by the operations section.

4.1.1.2. Operations section

The operations section is made up of an input data multiplexer, an output data multiplexer, a system control, the beam controls for transmission and reception as well as the radio unit (transmitter, receiver and antenna system). Its block diagram is shown in Figure 3.

The input data multiplexer funnels a multitude of input data channels together and brings them into a form so that they can be sent out. The processed data then are fed into the transmitter and sent out by the antenna system.

The output data demultiplexer accepts the data received by the receiver and the antenna system, processes them and splits them into the individual output channels.

The system control controls all operating sequences in the base station. It supplies time frame information for transmission and reception. It also administates beam control operations.

The beam controls control the beam directions of the antenna system in a way that the beam lobes of the transmit as well as the receive antenna system always point to the subscriber station to be adressed at the moment.

The antenna system is a system in which beam direction for transmission and reception can be controlled separately. This may be done either by diplexer elements at the individual antenna elements or by means of separate antenna systems for transmission and reception.

Transmitter and receiver are largely conventional and without any peculiarities.

4.1.1.2.1. Input data multiplexer base station

The input data multiplexer of the base station appropriately processes the data coming from a plurality of input channels and funnels them together for transmission. Its block diagram is shown in Figure 4.

The data from the input channels first are fed into a unit that collects the data stream during defined time intervals, transforming it into raw packets. In a next step various control information is added to these raw packets.

These are:

- the most recently measured value of the propagation delay

(from system control)

- time slot information for next packet to be sent by subscriber station (time slot position and length, from system control)

- time of transmission and packet length

- packet acknowledgement information

- target adress

- information how well the last received packet from this subscriber station hit into its assigned time slot

The thus completed raw packets then are fed into the packet buffers, provided with ECC/CRC information and entered into the buffer queue.

The packet buffers receive acknowledge and error information from the output data demultiplexer. They serve to remove packets acknowledged by the subscriber station from the buffer queue. If packets sent out are not acknowledged within a predefined time span they are repeated.

The filling level of the individual buffers is constantly reported to system control. System control therefrom determines the capacity requirements of the individual channels and correspondingly assigns narrower or wider time slots.

The completed packets now are available at the transmit multiplexer. It is completely under control of system control, selecting a packet from the selected packet buffer and feeding it in serialized form into the transmitter at high speed.

4.1.1.2.2. Output data demultiplexer base station

The block diagram of the output data demultiplexer is shown in Figure 5. It gets a - more or less continuous - stream of data packets from the receiver. They are first read into a buffer. From there they are fed into a checking unit checking the packets for errors and correcting them, if required. If this is impossible, they are discarded. Next the adress is extracted and the time of reception is determined. Then various control information is extracted. They are:

- adress information of the received packet (to output data demultiplexer for generating acknowledge information)

- time position of the received packet (to system control)

- time position of the received packet at subscriber station (to system control)

- time position of the last received packet at subscriber station (to system control)

This information serves to determine propagation delay

- field strength of the received packet (to system control)

This information serves to exactly point the beam of the receive antenna to the subscriber station

- field strength of the last received packet at subscriber station (to system control)

This information serves to exactly point the beam of the transmit antenna to the subscriber station

- Acknowledge information (to the packet buffer of the input data multiplexer)

This information indicates which packets have been correctly received by the subscriber station. Acknowledged packets are removed from the transmit queue. If transmitted packets are not acknowledged within due time, they are retransmitted.

- status information (to system control)

This information serves to determine time slot width for the individual subscriber stations according to the respective traffic requirements.

The remaining "payload information" of the individual packets now is fed into the receive demultiplexer. It in turn feeds them - under control of the adress extraction stage - to the respective output channels.

4.1.1.2.3. System control base station

System control handles all operational sequences in the system. Broadly speaking these are time slot administration and associated control operations as well as controlling the beam headings of the antenna system. Its block diagram is shown in Figure 6.

4.1.1.2.3.1. Central clock and adress cycler

A central unit of system control is the central clock. This is a highly stable quartz crystal based clock generator. It should have a short term stability of 0.1 ppm or better.

The central clock controls the adress cycler which cycles through the adresses of the various registers. It is in fact a kind of real time clock that constantly provides system time.

4.1.1.2.3.2. The time slot data registers

The time slot data register transmission and time slot data register reception contain the time slot information needed for controlling the transmit multiplexer of the input data multiplexer and the receive demultiplexer of the output data demultiplexer, respectively. The time slot data registers are organized in the form of a list in which the time positions of the start and the end of a transmission / reception are related to a subscriber station identification / channel identification (this is in the case a subscriber station runs more than one channel). In response to actual system time provided by the adress cycler these registers output the subscriber station identification belonging to the time slot the adress cycler is pointing to.

The subscriber / channel identification provided by the time slot data register transmission is directly fed into the transmit multiplexer of the input data multiplexer. The transmit multiplexer thus takes a packet from the selected packet buffer, serializes it and sends it at high speed to the radio set and from there to the respective subscriber station.

The data output by the time slot data register reception serve to check if the incoming packets arrive at exactly the scheduled time positions. Should there be any deviation, a correction value is calculated and sent to the respective subscriber station to enable it to fine tune its time scale.

4.1.1.2.3.3. The time slot data administration units

The time slot data registers are controlled by two time slot data administration units. There are two, one for transmission, another for reception.

4.1.1.2.3.3.1. The time slot data administration transmission
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The time slot data administration transmission gets information from the input data multiplexer about the filling level of the various packet buffers. It determines from these values the transfer requirements of the respective channels and calculates therefrom the time slot width for the respective channels. The results then are written into the time slot data register transmission.

They are also reported to the beam control register transmission to enable it to set the required beam heading at the right time.

The time slot data administration transmission further obtains information from the login communications unit about subscriber stations wishing to start active communications and assigns them a transmit time slot. At the same time the received direction information is forwarded to the beam control data register transmission.

The detailed operation is shown in Figure 7. Explanation starts at the loop at top center. There the time slot data administation transmission checks all the packet buffers of the input data multiplexer for their filling level. It then checks whether there have been any login requests from the login unit. If there are any, the transmit schedule list is checked whether there is any space available for additional time slots. If there is none available, the login unit is informed that a login is not possible at the moment. The time slot data administration transmission then returns to checking all the packet buffers of the input data multiplexer for their filling level.

If there is space available, a preliminary assignment for a transmit time slot is made. It then arrives at point A.

If there is no login request, a check for a change in traffic requirements is done. If there is none, the time slot data administration transmission returns to checking all the packet buffers of the input data multiplexer for their filling level.

If there is a change in traffic requirements, it arrives at point A.

At point A, a calculation of the required packet lengths is carried out using the buffer size and login data. After having done this for the complete set of logged in stations, all packet lengths are summed up and compared with the total available transmit cycle. If the result is bigger, the packet lengths are adjusted until the sum fits into a complete transmit cycle.

Subsequently a list of logged in subscriber stations / channels versus time slot data (time position, length) is created. This list is now submitted to the transmit / receive collision avoidance at the subscriber stations to check whether there are any transmit / receive overlaps at any of the subscriber stations. Thsi must be avoided as the subscriber stations are equipped with a transmit / receive switch for simplicity reasons and cannot transmit and receive simultaneously. If there are any such overlaps, the transmit / receive collision avoidance at the subscriber stations suitably changes the sequence in the time slot data list. If no overlaps are detected, it changes nothing. Finally the list is sent to the time slot data register transmission and the beam steering data register transmission. The new schedule is put into effect at the beginning of the next transmit cycle.

The time slot data administration transmission then returns to checking all the packet buffers of the input data multiplexer for their filling level.

4.1.1.2.3.3.2. The time slot data administration reception

The time slot data administration reception gets information from the output data demultiplexer about thetraffic requirements of the subscriber stations. It determines from these values the transfer requirements of the respective channels and calculates therefrom the time slot width for them. The results then are sent to the packet buffers input data multiplexer to be sent to the subscriber stations.

They are also written into the time slot data register reception and reported to the beam control register reception to enable it to set the required beam heading at the right time.

The time slot data administration reception further obtains information from the login communications unit about subscriber stations wishing to start active communications and assigns them a receive time slot. At the same time the received direction information is forwarded to the beam control data register reception.

The detailed operation is shown in Figure 8. Explanation starts at the loop at top center. There the time slot data administation reception checks the status information of the subscriber stations which is provided by the output data demultiplexer. It then checks whether there have been any login requests from the login unit. If there are any, the receive schedule list is checked whether there is any space available for additional time slots. If there is none available, the login unit is informed that a login is not possible at the moment. The time slot data administration reception then returns to checking the traffic status information of the subscriber stations.

If there is space available, a preliminary assignment for a transmit time slot is made. It then arrives at point B.

If there is no login request, a check for a change in traffic requirements is done. If there is none, the time slot data administration reception returns to checking the traffic status information of the subscriber stations.

If there is a change in traffic requirements, it arrives at point B.

At point B, a calculation of the required packet lengths is carried out using the buffer size and login data. After having done this for the complete set of logged in stations, all packet lengths are summed up and compared with the total available transmit cycle. If the result is bigger, the packet lengths are adjusted until the sum fits into a complete transmit cycle.

Subsequently a list of logged in subscriber stations / channels versus time slot data (time position, length) is created. This list is now submitted to the transmit / receive collision avoidance at the subscriber stations to check whether there are any transmit / receive overlaps at any of the subscriber stations. This must be avoided as the subscriber stations are equipped with a transmit / receive switch for simplicity reasons and cannot transmit and receive simultaneously. If there are any such overlaps, the transmit / receive collision avoidance at the subscriber stations suitably changes the sequence in the time slot data list. If no overlaps are detected, it changes nothing. Now a check is carried out whether there have been any successful login requests at the beginning of the sequence of actions. If any are detected, their respective data are sent to the login unit to be sent to the stations starting active communications.

Finally the list is sent to the input data multiplexer to be sent to the subscriber stations logged in. It is also sent to the time slot data register reception and the beam steering data register reception. The new schedule is put into effect at the beginning of the next transmit cycle.

The time slot data administration reception then returns to checking the traffic status information of the subscriber stations.

4.1.1.2.3.3.3. The transmit / receive collision avoidance at subscriber station

The two time slot data administration units are controlled by a transmit/receive collision prevention unit in a way that there is never an overlap of a transmit and a receive time slot at a subscriber station. This is required, because the subscriber stations use a transmit/receive switch.

The detailed operation is shown in Figure 9. Explanation starts on top left. Here the transmit / receive collision avoidance at subscriber station waits for requests of either the time slot data administration transmission or the time slot data administration reception to carry out a schedule check. If there is any, it proceeds to calculating a list of arrival time slots at the subscriber station from the transmit schedule list provided by the time slot data administration transmission and a list of transmission time slots at the subscriber station from the receive schedule list provided by the time slot data administration reception.

Now, as the transmit / receive collision avoidance at subscriber station has complete information about the situation at each subscriber station, it proceeds to comparing the two lists and checking if there are any overlaps between transmission and reception at any of the subscriber stations. If any are detected, the order of thetiming sequences in the lists are interchanged so long until all overlaps have been removed. Then the reordering loop is left.

If no transmit / receive overlaps have been detected in the first place this fact is communicated to the time slot data administration transmission and the time slot data administration reception. They then can proceed with their sequence of actions without rearranging their respective lists. If, however, transmit / receive overlaps have been detected, instructions are given to the time slot data administration transmission and the time slot data administration reception about the necessary rearrangement measures in their lists so that they can carry them out.

After having done so, the transmit / receive collision avoidance at subscriber station returns to waiting for requests of either the time slot data administration transmission or the time slot data administration reception to carry out a schedule check.

4.1.1.2.3.3.3. The beam control data registers

The two beam control data registers contain the direction data of the individual subscriber stations needed for directing the beam lobes of the antenna system onto the subscriber stations. To eliminate possible deviations the dither controls are required. They constantly move the beam lobes around the exact heading. By constantly comparing the measured field strength with the respective beam heading deviations from the correct heading can be detected and eliminated.

To determine the precise transmit beam heading the transmission of the field strength values by the subscriber stations is required. In case of the receive beam heading the required values are directly available.

4.1.1.2.3.3.3. The dither controls

The purpose of the dither controls is to move the beam lobes around the exact direction towards each subscriber station, collect the associated field strength values and use them in conjunction with the known properties of the steerable beam antennas to determine whether the beam heading values in the beam steering data registers are still correct, and, if there are any deviations, to correct them.

To do so, each time a beam is pointed to a particular station, a value from the dither table is added. The dither table contains three dither vectors. They all have the same size, but a different direction. Each of them has an angle of 120 degrees to each other (in fact any other arrangement with more vectors and different angles might also be used, but would be more complicated). Each time a particular station is adressed, the next value from the dither table is added to the respective value in the beam steering data register, until all values in the dither table have been used. After that, the whole action is repeated.

At each dither step the associated field strength value is collected and written into the dither table into the column of the associated dither value. There is, in fact, a row in the dither table for each subscriber station logged in.

After having used all three dither values the associated field strength values for each station can be taken and used to determine the necessary corrections to be entered into the beam steering data register.

The sequence of actions carried out for one subscriber station is shown in Figure 10. Explanation starts at top left. When the selected subscriber station is to be accessed, the cycle count value is checked. If it is larger than two, it is set to zero. Further, this means that all dither values have already been applies to this particular station and that a complete set of field strength values is available. The dither control then proceeds to reading these three field strength values and to calculate the deviation of the beam direction from the correct value. Using this value it corrects the beam heading entry in the beam steering data register. It then proceeds to point C.

If the cycle count is not bigger than two, that means that the set of field strength values is not yet complete. The process then directly proceeds to point C.

Following point C, the dither value associated with the cycle count is read from the dither table. The dither value is then added to the beam heading value taken from the beam steering data register and the antenna beam lobe is set to the thus calculated direction. Now the associated field strength value is read in. In case of the reception system, this value comes directly from the receiver, in case of the transmission system, it is a value returned by the associated subscriber station. In any case, the associated value is written into the appropriate position in the respective dither table. Finally, the cycle count is incremented by one and the dither control waits for the next access to that particular subscriber station.

As has already been mentioned, there are two dither controls, one for transmission and one for reception. Their operation is, however, completely identical.

4.1.1.2.4. RF system base station

The block diagram of the RF system of the base station is shown in Figure 11. It consists of a largely conventional transmitter and receiver as well as a transmit and a receive antenna the beams of which can be controlled electronically (phased array). As a peculiarity it should be mentioned that the demodulator should be designed to enable it to synchronize rapidly on an incoming signal.

For reasons of simplicity QPSK is provided as its modulation, however, for extremely high data rates QAM may be used in order to save bandwidth.

Also for reasons of simplicity separate beam steerable antennas are used at the base station. It is, however, also possible to use a combined antenna system which has separate beam steering facilities for transmission and reception. In the context of a phased array, this may be a diplexer and two separate phase controller and power combiners at each element (or subgroup of elements).

As a beam steerable antenna any known design may be used: phased arrays, arrays of directional antennas where the antenna beaming in the required direction is activated etc.

4.1.2. Subscriber station

The general layout of the subscriber station is similar to that of the base station, it, however lacks some parts and others are considerably simpler. Its block diagram is shown in Figure 12. A subscriber station is either designed for one subscriber or a number of them (apartment block, company).

It is made up of a login unit, an input data multiplexer, an output data demultiplexer, a system control as well as a radio unit (transmitter, receiver and antenna system).

The input data multiplexer funnels a multitude of input data channels together and brings them into a form so that they can be sent out. The processed data then are fed into the transmitter and sent out by the antenna system.

The output data demultiplexer accepts the data received by the receiver and the antenna system, processes them and splits them into the individual output channels.

The system control controls all operating sequences in the base station. It supplies time frame information for transmission and reception.

Login control is activated if a communications link to the base station is to be established. In order to do so, it sends a login request. Due to the fact that login communications is carried out with low bandwidth, the login unit switches the radio unit to low bandwidth mode. It then carries out the login data exchange with the base station and forwards the login data to system control and passes control to it. The radio unit then is reset to wideband mode.

It may also receive a request from the base station requesting that it makes a login request. This is required if an incoming communications request towards a subscriber station is to be made.

4.1.2.1. Login unit

Figure 13 shows the sequence of actions at the user station side.

If the user station wants to log in at the base station it sends a login request packet containing its station identification to the login unit of the base station. It then waits for a reply. If no reply is received within a certain time, the request is repeated.

As soon as a reply packet is received, the time of its arrival is determined. Then a check is done if the reply packet contains a "no channel available" message. If this is the case, the login sequence of events is ended and no communications link is built up.

If no such message is found the time slot assignment data are extracted from the reply packet. In the next step the time of reception of the login request packet at the base station is extracted from the reply packet. Then the time of transmission of the reply packet at the base station is extracted from the reply packet. Now the propagation delay between the user station and the base station is calculated. This is done in the following way: First, the time when the login request packet was sent and when the reply packet from the base station was received are deducted from each other. This yields the time span between login request and reply from the base station. In order to obtain the round trip delay time between subscriber station and base station the time span between time of reception of the login request packet and the time of transmission of the reply packet at the base station must be deducted. In order to obtain this value, the time of reception of the login request packet and the time of transmission of the reply packet at the base station are deducted from each other. Then the resulting round trip delay time is divided by two to obtain the propagation delay between subscriber station and base station.

Now, having all necessary values a relationship between the time bases of the subscriber station and base station can be established. Then the exact time position of the receive slot of the base station, as seen from the user station is determined. Then main communications is started. Now a short packet is sent at the center of the reception time slot of the base station. As the base station always sends deviation information between the assigned time slot and the actual arrival of a packet, the subscriber station now waits until the arrival of such a packet from the base station. After having received the reply from the base station, the deviation information contained therein is used to finely correct the timing relationship between the base station and the local time bases. Then final communications for actual data transfer is started.

4.1.2.2. Input data multiplexer subscriber station

The input data multiplexer of the subscriber station appropriately processes the data coming from a plurality of input channels and funnels them together for transmission. Its block diagram is shown in Figure 14.

The data from the input channels first are fed into a unit that collects the data stream during defined time intervals, transforming it into raw packets. In a next step various control information is added to these raw packets.

These are:

- time position of the last packet received (from output data demultiplexer)
- field strength of the last packet received (from output data demultiplexer)
- packet acknowledge information
- target adress
- capacity requirements

The thus completed raw packets then are fed into the packet buffers, provided with ECC/CRC information and entered into the buffer queue.

The packet buffers receive acknowledge and error information from the output data demultiplexer. They serve to remove packets acknowledged by the subscriber station from the buffer queue. If packets sent out are not acknowledged within a predefined time span they are repeated.

The filling level of the individual buffers is constantly reported to system control. System control therefrom determines the capacity requirements of the individual channels and communicates it to the base station.

The completed packets now are available at the transmit multiplexer. It is completely under control of system control, selecting a packet from the selected packet buffer and feeding it in serialized form into the transmitter at high speed.

4.1.2.3. Output data demultiplexer subscriber station

The block diagram of theoutput data demultiplexer is shown in Figure 15. It gets a - more or less continuous - stream of data packets from the receiver. They are first read into a buffer. From there they are fed into a checking unit checking the packets for errors and correcting them, if required. If this is impossible, they are discarded. Packets not adressed to the local subscriber station are also discarded. Next the adress is extracted and the time of reception is determined. Then various control information is extracted. They are:

- adress information of the received packet (to output data demultiplexer for generating acknowledge information)

- time position of the received packet (to output data demultiplexer, information to be sent back to base station for propagation delay measurement)

- field strength of the received packet (to output data demultiplexer, information to be sent back to base station for beam control of base station transmission beam)

- Acknowledge information (to the packet buffer of the input data multiplexer to remove acknowledged packets)

- status information (to system control)

The remaining "payload information" of the individual packets now is fed into the receive demultiplexer. It in turn feeds them - under control of the adress extraction stage - to the respective output channels.

4.1.2.4. System control subscriber station

System control handles all operational sequences in the system. Its block diagram is shown in Figure 16. In the context of the subscriber station, these are relatively few, in fact providing real time clock, implementing the transmit time slot schedule and determining the traffic requirements.

4.1.2.4.1. Central clock and adress cycler

A central unit of system control is the central clock. This is a highly stable quartz crystal based clock generator. It should have a short term stability of 0.1 ppm or better.

The central clock controls the adress cycler which cycles through the adresses of the time slot data register transmission. It is in fact a kind of real time clock that constantly provides system time.

4.1.2.4.2. The time slot data register transmission

The time slot data register transmission controls the transmit multiplexer of the input data multiplexer. It contains the time slot information required for this.

The time slot data register is organized in the form of a list in which the time positions of the start and the end of a transmission are related to a channel identification in the case a subscriber station runs more than one channel. In response to actual system time provided by the adress cycler this register outputs the channel identification belonging to the time slot the adress cycler is pointing to.

The channel identification provided by the time slot data register transmission is directly fed into the transmit multiplexer of the input data multiplexer. The transmit multiplexer thus takes a packet from the selected packet buffer, serializes it and sends it at high speed to the radio set and from there to the respective subscriber station.

The data output by the time slot data register reception serve to check if the incoming packets arrive at exactly the scheduled time positions. Should there be any deviation, a correction value is calculated and sent to the respective subscriber station to enable it to fine tune its time scale.

4.1.2.4.3. The time slot data administration unit transmission
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The time slot data register transmission is controlled by the time slot data administration unit transmission.

This unit receives actualized transmit time window data from the base station and feeds them into the time slot data register transmission.

It also stops transmission if for some reason the time slot window data - which are to arrive at regular intervals - do not arrive as they are to be expected until another time slot window data set can be received. This is crucial to avoid using an outdated timing scheme that could cause interference with other stations.

It also obtains deviation information from the base station indicating how precisely the transmitted packets hit into the assigned time slot. This information is used to adjust transmit timing in order to eliminate this deviation.

4.1.2.4.4. Traffic demand determination

The traffic demand determination or short demand determination receives data about the filling levels of the individual packet buffers. It determines capacity requirement data for the individual channels and forwards this value to the base station.

The clock signal of the central clock is also used by the output data demultiplexer to determine the time of reception values of the individual packets.

4.1.2.5. RF system subscriber station

The RF system subscriber station is designed similarly as the one of the base station, but has additionally a narrow band mode for login.

4.2. A satellite based communications system

The satellite based communications system described in the following serves to link a multitude of subscribers scattered on the earths surface to a satellite. Much like the ground based wireless local loop system just set out it is data transparent, that is, data fed into it one one end will come out on the other end unaffectedly. Thus the system can be used in any thinkable protocol environment, be it ISDN. ATM, or anything else.

The satellite based communications system is made up of a network of orbiting satellites, that are all connected with each other with radio inter satellite link systems. They each carry an onboad switching system that can either link a particular subscriber station with another one linked to the same satellite or - using the inter satellite link system - with a subscriber station linked to another satellite. There is also the possibility to link a subscriber into the conventional ground based communications infrastructure via gateway stations. These gateway stations are designed in exactly the same way as subscriber stations, except that they are connected with the ground based global telecommunications infrastructure.

The embodiment described here uses adjusts channel capacity to actual requirements. A system that assigns a fixed channel capacity, that is fixed time slot widths, to each channel without any demand adjustment is also possible and would be simpler. It is, however, less efficient. In some applications with fixed channel width transfer protocols (e. g. ISDN) it may, however, make sense.

4.2.1. Base station

The base station - generally speaking - is made up of an operations section handling normal communications operations and a login section accepting and handling login requests of stations having been inactive so far.

4.2.1.2. Login section

The login section serves to enable subscriber stations, which have been inactive so far, to set up an active communications link to the base station. Its block diagram is shown in Figure 17.

The bandwidths used for this are much narrower than those used in an active communications link. This poses no problem because the amounts of data to be transferred are small and communications furthermore only take place before setting up an active communications link, in other words, communications via the login system are rather rare.

4.2.1.2.1. The scanning approach

Figure 18 shows a base station scanning an area for stations wishing to log in with its login / search steerable beam antenna as well as a subscriber station scanning all the sky above a predefined grazing angle for a signal from a base station. Scanning is done in a sector - wise manner, that is, the total service area angular area of the login / search antenna is subdivided into individual sectors or cells the width of the beamwidth of the login / search antenna. Scanning is done by stepping from one sector to the next, until all sectors have been scanned, and then starting the same action all over again, thus constantly scanning the service area of the antenna.

Except in the case of geostationary systems normally there will be a relative speed between the satellite and the ground station. This speed is a function of the slant angle on the ground and a number of orbital parameters - finally a paraneter of the scan beam angle of the login antenna. Therefore the transmit and receive frequency of the radio set is varied in dependence of the pointing direction of the login antenna in order to alway provide the same transmit and receive frequency on the ground.

Operations at a subscriber station is much similar. Here, too, the service area of the antenna is subdivided in sectors or cells the beamwidth of the unit's antenna, whereby the service area is all the area above the grazing angle.

There is, however, a difference in the speed of scanning. If the base station scans with a certain speed and takes a certain time to complete a scan of its entire area, the subscriber station advances its beam from one sector to the next in that time. This is so in order to ensure that the beam of the subscriber station antenna stays pointed long enough onto the same spot that it gets at least one scan of the base station antenna onto it if it happens to point into the right direction.

4.2.1.2.2. General layout of the login system

Figure 17 shows the block diagram of the login unit in the base station. In the base station the login system is a dedicated one and serves for login purposes exclusively. It is made up of a login communications unit that controls the login process itself. It is connected with a login radio set, a PN correlator, a PN sequencer and a login antenna beam steering unit. The radio set is made up of a transmitter, a receiver, a diplexer and a beam steerable login antenna. The beam direction of the login antenna is controlled by the beam steering unit. There is also a doppler compensator that gets beam heading data from the beam steering unit as well as orbital data from system control and calculates therefrom doppler shift. The doppler shift value is entered into the transmitter and the receiver and controls these units so that the apparent operating frequency at the subscriber station is everywhere the same. The login communications unit also has a link to the main communications system that takes over when login operations are finished.

4.2.1.2.3. Overview of a login process

As has been set out already, the base station as well as the subscriber station use beam steerable antennas and scan their respective areas of service. The satellite station preferably does this at a high speed and sends a beacon signal all the time. The subscriber station does this at a much lower speed, preferably one step per full scan of the base station antenna. As soon as the subscriber station gets a signal from the base station it stops scanning and starts transmitting a login request signal. This signal is repeated cyclically for a time span that is longer than the time span the base station login unit needs to scan its entire service area. This is necessary because at the time the ground station receives a signal from the base station the base station antenna already points somewhere else due to the long propagtation delays inherent in satellite links. The only chance for the ground station to be heard is to transmit long enough that the base station detects its signal during its scan operation. As soon as the base station detects a signal it stops scanning and tries to recover information from the signal. Then information is exchanged to finally establish an active communications link.

The time span the subscriber stations sends is - within certain limits - determined stochastically. This is required, because, if there is more than one station wishing to login in the same sector they jam each other's transmission. If, however, their transmissions are of a length determined partly by chance and thus different, the one that happens to have the longest transmission can be decoded and gets a chance to login.

Measures have to be taken in the process that the "losers" in the process get a chance after the successful login of the "winner" station.

4.2.1.2.4. Doppler shift compensator

Figure 19 shows the operations carried out in the satellite base station for providing doppler shift compensation. Explanation starts on top.

The process starts by checking whether beam direction has been changed recently. If this is the case, the new beam direction is read in and the resulting slant speed vector calculated. Then the actual position over ground, the subsatellite point is calculated. From this the radial speed vector resulting from the earth rotation is determined. Now, using a vector addition between the slant speed vector and the radial earth rotation speed vector is calculated. After having done so the doppler deviation can be determined and the radio set instructed to change its frequency accordingly.

4.2.1.2.5. Login sequence as seen from the base station

Figure 20 shows a complete login process as carried out by the base station login system. Explanation starts at top left.

Normally the whole service area of the login antenna is scanned for login signals with the transmitter constantly on to allow subscriber stations to fix base station direction. However, if the presence of a signal is detected, the scanning is suspended and the beam stays in the respective sector. Now the packet being received is time stamped. Then the time of transmission and the subscriber station identification are extracted. This sequence of action is repeated until the transmission from the subscriber station ends.

Thus, after the transmission has been terminated, the last logged values are available in a receive buffer memory. The base station login transmitter now prepares a reply message into which it puts the identification code of the subscriber station, the last time stamp recovered from the subscriber station transmitter, its own time stamp at which the login request packet was received, the origin of the PN signal superimposed to the signal to be transmitted, as well as the time of transmission of the reply packet. Then the packet is sent and a PN signal superimposed onto the transmitted signal is applied.

As soon as the transmission from the base station is terminated at the subscriber station, the subscriber station transmitter starts sending a reply. As soon as said reply arrives at the base station login receiver, the coarse round trip delay time value evaluated by the subscriber station is extracted. This value is used to preset the PN correlator which now attempts to lock onto the PN signal superimposed on the signal sent by the subscriber station. As soon as a lock is achieved, the origin of the PN signal as received at the base station can be determined. Then the time offset data between the origin of the PN signal as received onboard the subscriber station and the PN signal sent out by the subscriber station is read from the uplinked signal and the exact round trip delay is calculated. During reception of the reply signal from the subscriber station once again the receive beam is dithered and the exact beam heading determined.

If the subscriber station fails to reply or its signal cannot be received, login communications is terminated.

These data now are communicated to the main communications unit and inclusion into the communications queue is requested. The main communication unit now tries to do so. If no time slot pair can be made available, a "no channel available" message is sent to the subscriber station and login communications are terminated.

If, however, a time slot pair is available, the time slot data are sent to the login unit for transmission to the subscriber station. The login unit adds the precise round trip delay data and the sends the information to the subscriber station. Then it terminates communications with the subscriber station as the main communications unit takes over.

The login unit now listens if there are more stations wishing to login in the same sector. If within a predetermined time none are heard the login unit returns to scanning its service area to detect other stations wishing to log in.

4.2.1.3. Operations section

The operations section is made up of an input data multiplexer, an output data multiplexer, a system control, the beam controls for transmission and reception, the radio unit (transmitter, receiver and antenna system), the onboard switching system, the interlink system and its associated interlink antenna system as well as the active / standby control unit. Its block diagram is shown in Figure 21.

The input data multiplexer funnels a multitude of input data channels together and brings them into a form so that they can be sent out. The processed data then are fed into the transmitter and sent out by the antenna system.

The output data demultiplexer accepts the data received by the receiver and the antenna system, processes them and splits them into the individual output channels.

The system control controls all operating sequences in the base station. It supplies time frame information for transmission and reception. It also administates beam control operations.

The beam controls control the beam directions of the antenna system in a way that the beam lobes of the transmit as well as the receive antenna system always point to the subscriber station to be adressed at the moment.

The antenna system is a system in which beam direction for transmission and reception can be controlled separately. This may be done either by diplexer elements at the individual antenna elements or by means of separate antenna systems for transmission and reception.

Transmitter and receiver are largely conventional and without any peculiarities.

The onboard switching system principally serves the same system as switching systems do in any ground based communications infrastructure: it routes a data channel from a source to a destination. This may be a subscriber on the same satellite having connection to another subscriber on it, it may also happen that only the source or the destination is on the same satellite, or that they both are linked ot another satellite and are simply routed through in order to get together (through traffic routing / switching).

The interlink system and its associated interlink antenna system serve to link the satellite to adjacent satellites in the satellite network, either to route communications links originating (or ending) at itself to other source /destination satellites or to link satellites that have no direct contact with each other.

The active / standby control serves a particular purpose peculiar to satellite networks: due to the laws of celestial mechanics all satellite orbits must have the center of the earth in their orbital plane. This results in the fact that the subsatellite points of any system of orbits intersect somewhere, in other words, an equal distribution of satellites that the subsatellite points at any time are evenly distributed is not attainable. There will always be the situation that in some areas satellite subsatellite points are far away from each other and that at others there is a surplus of them. In this latter areas it is possible to "thin out" subsatellite points by shutting down some of the satellites, thus saving onboard power consumption. As the latter is always at a premium, this is clearly desirable.

4.2.1.3.1. Input data multiplexer base station

The input data multiplexer of the base station appropriately processes the data coming from a plurality of input channels and funnels them together for transmission. Its block diagram is shown in Figure 22.

The data from the input channels first are fed into a unit that collects the data stream during defined time intervals, transforming it into raw packets. In a next step various control information is added to these raw packets.

These are:

- the most recently measured value of the propagation delay (from system control)

- time slot information for next packet to be sent by subscriber station (time slot position and length, from system control)

- time of transmission and packet length

- packet acknowledgement information

- target adress

- information how well the last received packet from this subscriber station hit into its assigned time slot

The thus completed raw packets then are fed into the packet buffers, provided with ECC/CRC information and entered into the buffer queue.

The packet buffers receive acknowledge and error information from the output data demultiplexer. They serve to remove packets acknowledged by the subscriber station from the buffer queue. If packets sent out are not acknowledged within a predefined time span they are repeated.

The filling level of the individual buffers is constantly reported to system control. System control therefrom determines the capacity requirements of the individual channels and correspondingly assigns narrower or wider time slots.

The completed packets now are available at the transmit multiplexer. It is completely under control of system control, selecting a packet from the selected packet buffer and feeding it in serialized form into the transmitter at high speed.

4.2.1.3.2. Output data demultiplexer base station

The block diagram of the output data demultiplexer is shown in Figure 23. It gets a - more or less continuous - stream of data packets from the receiver. They are first read into a buffer. From there they are fed into a checking unit checking the packets for errors and correcting them, if required. If this is impossible, they are discarded. Next the adress is extracted and the time of reception is determined. Then various control information is extracted. They are:

- adress information of the received packet (to output data demultiplexer for generating acknowledge information)

- time position of the received packet (to system control)

- time position of the received packet at subscriber station (to system control)

- time position of the last received packet at subscriber station (to system control)

This information serves to determine propagation delay

- field strength of the received packet (to system control)

This information serves to exactly point the beam of the receive antenna to the subscriber station

- field strength of the last received packet at subscriber station (to system control)

This information serves to exactly point the beam of the transmit antenna to the subscriber station

- Acknowledge information (to the packet buffer of the input data multiplexer)

This information indicates which packets have been correctly received by the subscriber station. Acknowledged packets are removed from the transmit queue. If transmitted packets are not acknowledged within due time, they are retransmitted.

- status information (to system control)

This information serves to determine time slot width for the individual subscriber stations according to the respective traffic requirements.

The remaining "payload information" of the individual packets now is fed into the receive demultiplexer. It in turn feeds them - under control of the adress extraction stage - to the respective output channels.

4.2.1.3.3. System control base station

System control handles all operational sequences in the system. Broadly speaking these are time slot administration and associated control operations as well as controlling the beam headings of the antenna system. Its block diagram is shown in Figure 24.

4.2.1.3.3.1. Central clock and adress cycler

A central unit of system control is the central clock. This is a highly stable quartz crystal based clock generator. It should have a short term stability of 0.1 ppm or better.

The central clock controls the adress cycler which cycles through the adresses of the various registers. It is in fact a kind of real time clock that constantly provides system time.

4.2.1.3.3.2. The time slot data registers

The time slot data register transmission and time slot data register reception contain the time slot information needed for controlling the transmit multiplexer of the input data multiplexer and the receive demultiplexer of the output data demultiplexer, respectively. The time slot data registers are organized in the form of a list in which the time positions of the start and the end of a transmission / reception are related to a subscriber station identification / channel identification (this is in the case a subscriber station runs more than one channel). In response to actual system time provided by the adress cycler these registers output the subscriber station identification belonging to the time slot the adress cycler is pointing to.

The subscriber / channel identification provided by the time slot data register transmission is directly fed into the transmit multiplexer of the input data multiplexer. The transmit multiplexer thus takes a packet from the selected packet buffer, serializes it and sends it at high speed to the radio set and from there to the respective subscriber station.

The data output by the time slot data register reception serve to check if the incoming packets arrive at exactly the scheduled time positions. Should there be any deviation, a correction value is calculated and sent to the respective subscriber station to enable it to fine tune its time scale.

4.2.1.3.3.3. The time slot data administration units

The time slot data registers are controlled by two time slot data administration units. There are two, one for transmission, another for reception.

4.2.1.3.3.3.1. The time slot data administration transmission
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The time slot data administration transmission gets information from the input data multiplexer about the filling level of the various packet buffers. It determines from these values the transfer requirements of the respective channels and calculates therefrom the time slot width for the respective channels. The results then are written into the time slot data register transmission.

They are also reported to the beam control register transmission to enable it to set the required beam heading at the right time.

The time slot data administration transmission further obtains information from the login communications unit about subscriber stations wishing to start active communications and assigns them a transmit time slot. At the same time the received direction information is forwarded to the beam control data register transmission.

The detailed operation is shown in Fig. 25. Explanation starts at the loop at top center. There the time slot data administation transmission checks all the packet buffers of the input data multiplexer for their filling level. It then checks whether there have been any login requests from the login unit. If there are any, the transmit schedule list is checked whether there is any space available for additional time slots. If there is none available, the login unit is informed that a login is not possible at the moment. The time slot data administration transmission then returns to checking all the packet buffers of the input data multiplexer for their filling level.

If there is space available, a preliminary assignment for a transmit time slot is made. It then arrives at point A.

If there is no login request, a check for a change in traffic requirements is done. If there is none, the time slot data administration transmission returns to checking all the packet buffers of the input data multiplexer for their filling level.

If there is a change in traffic requirements, it arrives at point A.

At point A, a calculation of the required packet lengths is carried out using the buffer size and login data. After having done this for the complete set of logged in stations, all packet lengths are summed up and compared with the total available transmit cycle. If the result is bigger, the packet lengths are adjusted until the sum fits into a complete transmit cycle.

Subsequently a list of logged in subscriber stations / channels versus time slot data (time position, length) is created. This list is now submitted to the transmit /

receive collision avoidance at the subscriber stations to check whether there are any transmit / receive overlaps at any of the subscriber stations. Thsi must be avoided as the subscriber stations are equipped with a transmit / receive switch for simplicity reasons and cannot transmit and receive simultaneously. If there are any such overlaps, the transmit / receive collision avoidance at the subscriber stations suitably changes the sequence in the time slot data list. If no overlaps are detected, it changes nothing. Finally the list is sent to the time slot data register transmission and the beam steering data register transmission. The new schedule is put into effect at the beginning of the next transmit cycle.

The time slot data administration transmission then returns to checking all the packet buffers of the input data multiplexer for their filling level.

4.2.1.3.3.3.2. The time slot data administration reception

The time slot data administration reception gets information from the output data demultiplexer about thetraffic requirements of the subscriber stations. It determines from these values the transfer requirements of the respective channels and calculates therefrom the time slot width for them. The results then are sent to the packet buffers input data multiplexer to be sent to the subscriber stations.

They are also written into the time slot data register reception and reported to the beam control register reception to enable it to set the required beam heading at the right time.

The time slot data administration reception further obtains information from the login communications unit about subscriber stations wishing to start active communications and assigns them a receive time slot. At the same time the received direction information is forwarded to the beam control data register reception.

The detailed operation is shown in Fig. 26. Explanation starts at the loop at top center. There the time slot data administation reception checks the status information of the subscriber stations which is provided by the output data demultiplexer. It then checks whether there have been any login requests from the login unit. If there are any, the receive schedule list is checked whether there is any space available for additional time slots. If there is none available, the login unit is informed that a login is not possible at the moment. The time slot data administration reception then returns to checking the traffic status information of the subscriber stations.

If there is space available, a preliminary assignment for a transmit time slot is made. It then arrives at point B.

If there is no login request, a check for a change in traffic requirements is done. If there is none, the time slot data administration reception returns to checking the traffic status information of the subscriber stations.

If there is a change in traffic requirements, it arrives at point B.

At point B, a calculation of the required packet lengths is carried out using the buffer size and login data. After having done this for the complete set of logged in stations, all packet lengths are summed up and compared with the total available transmit cycle. If the result is bigger, the packet lengths are adjusted until the sum fits into a complete transmit cycle.

Subsequently a list of logged in subscriber stations / channels versus time slot data (time position, length) is created. This list is now submitted to the transmit / receive collision avoidance at the subscriber stations to check whether there are any transmit / receive overlaps at any of the subscriber stations. This must be avoided as the subscriber stations are equipped with a transmit / receive switch for simplicity reasons and cannot transmit and receive simultaneously. If there are any such overlaps, the transmit / receive collision avoidance at the subscriber stations suitably changes the sequence in the time slot data list. If no overlaps are detected, it changes nothing. Now a check is carried out whether there have been any successful login requests at the beginning of the sequence of actions. If any are detected, their respective data are sent to the login unit to be sent to the stations starting active communications.

Finally the list is sent to the input data multiplexer to be sent to the subscriber stations logged in. It is also sent to the time slot data register reception and the beam steering data register reception. The new schedule is put into effect at the beginning of the next transmit cycle.

The time slot data administration reception then returns to checking the traffic status information of the subscriber stations.

4.2.1.3.3.3.3. The transmit / receive collision avoidance at subscriber station

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The two time slot data administration units are controlled by a transmit/receive collision prevention unit in a way that there is never an overlap of a transmit and a receive time slot at a subscriber station. This is required, because the subscriber stations use a transmit/receive switch.

The detailed operation is shown in Fig. 27. Explanation starts on top left. Here the transmit / receive collision avoidance at subscriber station waits for requests of either the time slot data administration transmission or the time slot data administration reception to carry out a schedule check. If there is any, it proceeds to calculating a list of arrival time slots at the subscriber station from the transmit schedule list provided by the time slot data administration transmission and a list of transmission time slots at the subscriber station from the receive schedule list provided by the time slot data administration reception.

It further uses the known relative movements of the subscriber stations with respect to the base station (satellite) to predict how the time slots at each subscriber station will move in time position.

Now, as the transmit / receive collision avoidance at subscriber station has complete information about the situation at each subscriber station, it proceeds to comparing the two lists and checking if there are any present or future overlaps between transmission and reception at any of the subscriber stations. If any are detected, the order of the timing sequences in the lists are interchanged so long until all overlaps have been removed. Then the reordering loop is left.

If no transmit / receive overlaps have been detected in the first place this fact is communicated to the time slot data administration transmission and the time slot data administration reception. They then can proceed with their sequence of actions without rearranging their respective lists. If, however, transmit / receive overlaps have been detected, instructions are given to the time slot data administration transmission and the time slot data administration reception about the necessary rearrangement measures in their lists so that they can carry them out.

After having done so, the transmit / receive collision avoidance at subscriber station returns to waiting for requests of either the time slot data administration transmission or the time slot data administration reception to carry out a schedule check.

1.1.1.3.3.3. The beam control data registers

The two beam control data registers contain the direction data of the individual subscriber stations needed for directing the beam lobes of the antenna system onto the subscriber stations. To eliminate possible deviations the dither controls are required. They constantly move the beam lobes around the exact heading. By constantly comparing the measured field strength with the respective beam heading deviations from the correct heading can be detected and eliminated.

To determine the precise transmit beam heading the transmission of the field strength values by the subscriber stations is required. In case of the receive beam heading the required values are directly available.

The beam control data registers also get attitude data from the attitude sensor. Thus, if the satellite changes attitude, the beam directions of the antennas are automatically corrected, so that they always point in the right direction, independent of any attitude changes.

4.2.1.3.3.3.3. The dither controls

The purpose of the dither controls is to move the beam lobes around the exact direction towards each subscriber station, collect the associated field strength values and use them in conjunction with the known properties of the steerable beam antennas to determine whether the beam heading values in the beam steering data registers are still correct, and, if there are any deviations, to correct them.

To do so, each time a beam is pointed to a particular station, a value from the dither table is added. The dither table contains three dither vectors. They all have the same size, but a different direction. Each of them has an angle of 120 degrees to each other (in fact any other arrangement with more vectors and different angles might also be used, but would be more complicated). Each time a particular station is adressed, the next value from the dither table is added to the respective value in the beam steering data register, until all values in the dither table have been used. After that, the whole action is repeated.

At each dither step the associated field strength value is collected and written into the dither table into the column of the associated dither value. There is, in fact, a row in the dither table for each subscriber station logged in.

After having used all three dither values the associated field strength values for each station can be taken and used to determine the necessary corrections to be entered into the beam steering data register.

The sequence of actions carried out for one subscriber station is shown in Fig. 28. Explanation starts at top left. When the selected subscriber station is to be accessed, the cycle count value is checked. If it is larger than two, it is set to zero. Further, this means that all dither values have already been applies to this particular station and that a complete set of field strength values is available. The dither control then proceeds to reading these three field strength values and to calculate the deviation of the beam direction from the correct value. Using this value it corrects the beam heading entry in the beam steering data register. It then proceeds to point C.

If the cycle count is not bigger than two, that means that the set of field strength values is not yet complete. The process then directly proceeds to point C.

Following point C, the dither value associated with the cycle count is read from the dither table. The dither value is then added to the beam heading value taken from the beam steering data register and the antenna beam lobe is set to the thus calculated direction. Now the associated field strength value is read in. In case of the reception system, this value comes directly from the receiver, in case of the transmission system, it is a value returned by the associated subscriber station. In any case, the associated value is written into the appropriate position in the respective dither table. Finally, the cycle count is incremented by one and the dither control waits for the next access to that particular subscriber station.

As has already been mentioned, there are two dither controls, one for transmission and one for reception. Their operation is, however, completely identical.

4.2.1.4. RF system base station

The block diagram of the RF system of the base station is shown in Figure 29. It consists of a largely conventional transmitter and receiver as well as a transmit and a receive antenna the beams of which can be controlled electronically (phased array). As a peculiarity it should be mentioned that the demodulator should be designed to enable it to synchronize rapidly on an incoming signal.

For reasons of simplicity QPSK is provided as its modulation, however, for extremely high data rates QAM may be used in order to save bandwidth.

For reasons of weight and space savings a combined antenna system which has separate beam steering facilities for transmission and reception has been selected. In the context of a phased array, this may be a diplexer and two separate phase controller and power combiners at each element (or subgroup of elements).

In principle separate beam steerable antennas could also be used at the base station. They are, however, not very desirable in a satellite.

As a beam steerable antenna any known design may be used: phased arrays, arrays of directional antennas where the antenna beaming in the required direction is activated etc.

4.2.1.5. Active / standby control

Figure 30 shows an orbital network with similar orbits and polar intersection of the orbital planes in a satellite communications network. For the sake of easier understanding, only two orbits are drawn. It is, however, evident to those skilled in the art that such an orbital network may be made up of just any number of of orbits and the common intersection point also needs not necessarily lie on the poles (in fact, in a multi orbital system there may even be a multitude of intersection points, but for the sake of ease of understanding a system with only two intersection points has been selected).

It can be easily seen from Figure 30 that distance between the orbit lines is biggest at the equator and diminishes towards the poles where it becomes very small. It cannot be made zero because that would involve the risk of a satellite collision.

In fact, the distance is simply the product of the maximum separation of the orbits, multiplied by the cosine of the latitude. As the condition to remove a satellite is that the distance between the remaining satellite must mot be greater than in the area where distance is largest, it becomes evident that a removal is possible in an area where - in this case latitudinal - distance is half of that at the equator. This means that the above cosine must become one half. The cosine becomes one half at a latitude of 60 degrees.

A complete integration over all orbits under the assumption of circular orbits with the same parametrs except orientation shows that the percentage of standby time for a satellite is abot 21 % on the average.

Figure 31 shows the more general case where there are dissimilar orbits with different orientations and different intersection points. For the sake of ease of understanding, only three are drawn. Hoever, it is easy to see, that there are intersections, too, and consequently areas where satellite density is higher than elsewhere. Her however, the algorithm for shutting down satellites is not so simple as in Figure 27. It depends on the individual orbits and their properties and has to be determined in detail for each individual arrangement of orbits.

Figure 32 shows the process in the network necessary to decide the shutdown of satellites. Explanation starts on top. The first step is to asess the present network topology. In order to use the appropriate parameters in each areas, area dependent parameters have to be entered into the topology data. These data are particularly data about end user density and terrain flatness. In areas where end user density is low and the terrain is flat, grazing angle and satellite density may be reduced without affecting service quality. Typical areas of this kind are the oceans.

As a next step the local traffic situation is analyzed. In heavily loaded areas it may be unwise to deactivate satellites, because that might increase traffic loading for the remaining satellites to unacceptable levels and in this case is to be avoided.

Then the congested areas are determined. In these areas the most closeup station configuration is sought for. Then it is decided whether deactivating a satellite allows a new network configuration with all ensuing distances below the predetermined maximum. If this is not possible the process proceeds towards the next area and carries out the above process there. If it is possible consequences of a deactivation on the loading situation are determined. If they are unacceptable, the process also branches towards the next area. If, however, this test also ends positively, said satellite is deactivated and the network in the area is restructured. Then the next possible candidate for deactivation is probed. If there are no more candidates in a particular area, the process branches inevitably at one of the decisions to the next area. There the same process is repeated. If all areas are cared for, the process returns to the top and starts from the beginning again.

Figure 33 shows the operations associated with the reactivation of satellites. Explanation starts on top, where the process monitors the areas containing satellites in standby mode. Again, like above, the area topology data are parametrized with the area parameters. Equipped with these data an area is analyzed for the distances between the satellites in it. If a distance exceeding the predetermined limit is found the inactive satellite in the area is reactivated and the network around it restructured. If everything remains within limits, nothing is changed. The process then proceeds to the next area. After having examined all areas, the process returns to the top and restarts from the beginning.

4.2.2. Subscriber station

The general layout of the subscriber station is similar to that of the base station, it, however lacks some parts and others are considerably simpler. Its block diagram is shown in Figure 34. A subscriber station is either designed for one subscriber or a number of them (apartment block, company).

It is made up of a login unit, an input data multiplexer, an output data demultiplexer, a system control, a beam control as well as a radio unit (transmitter, receiver and antenna system).

The input data multiplexer funnels a multitude of input data channels together and brings them into a form so that they can be sent out. The processed data then are fed into the transmitter and sent out by the antenna system.

The output data demultiplexer accepts the data received by the receiver and the antenna system, processes them and splits them into the individual output channels.

The system control controls all operating sequences in the base station. It supplies time frame information for transmission and reception.

Login control is activated if a communications link to the base station is to be established. In order to do so, it sends a login request. Due to the fact that login communications is carried out with low bandwidth, the login unit switches the radio unit to low bandwidth mode. It then carries out the login data exchange with the base station and forwards the login data to system control and passes control to it. The radio unit then is reset to wideband mode.

It may also receive a request from the base station requesting that it makes a login request. This is required if an incoming communications request towards a subscriber station is to be made.

4.2.2.1. Login control

A block diagram of the login control of the subscriber station is shown in Figure 35. It consists of the login control system itself, a PN correlator and a PN generator. These latter units are connected to the receiver and the transmitter, respectively. They serve to echo the PN signal back to the base station to precisely determine round trip delay.

4.2.2.1.1. Login sequence as seen from the subscriber station
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Figure 36 shows the corresponding operations in the subscriber station required for login. After having received an instruction to log into the network, the antenna starts scanning the sky above the grazing angle for a base station beacon signal. A soon as such a signal is detected, the scan operation is stopped and the transmitter activated. The transmitter now sends the station identification code together with a time stamp indicating the time of transmission of each instance of a login request packet. This transmission is carried out for at least a time span required by the base station to perform a complete scan of its service area. Then the transmission is stopped.

The receiver now waits until echo information comes back from the base station. If no reply is detected within a predetermined time, the above sequence of events is repeated.

If, however, a reply is detected, a check is done if the reply is for the local station or another one. If the latter is the case, the end of the login process for this latter station is waited for. Then another login attempt is made.

If the reply is for the local station, it is time stamped. Then the transmission time stamp of the original login request as received by the base station and the receive time stamp of the base station are extracted. Then the time of transmission of the reply packet and the origin time stamp of the superimposed PN signal are retrieved. Using this data, the coarse round trip delay can be calculated and the PN correlator be preset. After having locked onto the signal the origin of the PN signal is determined and the PN generator of the subscriber station synchronized to it. After the base station transmission is terminated, the subscriber station sends a reply signal with superimposed PN signal. In this signal the obtained coarse round trip data and the origin of the superimposed PN signal are included.

After the end of this transmission, the receiver again waits for an answer from the base station. First, a check is done whether a "no channel available" message is contained in the reply packet. If this is the case, login communications is terminated.

If this is not the case, the results from the exact round trip delay measurement are extracted and a relationship is established between the base station and local time bases. Then the transmit and receive time slot data for main communications are extracted. After this contact with the login system of the base station is terminated and active communications is started.

Now a short packet is sent at the center of the reception time slot of the base station. As the base station always sends deviation information between the assigned time slot and the actual arrival of a packet, the subscriber station now waits until the arrival of such a packet from the base station. After having received the reply from the base station, the deviation information contained therein is used to finely correct the timing relationship between the base station and the local time bases. Then final communications for actual data transfer is started.

4.2.2.2. Input data multiplexer subscriber station

The input data multiplexer of the subscriber station appropriately processes the data coming from a plurality of input channels and funnels them together for transmission. Its block diagram is shown in Figure 37.

The data from the input channels first are fed into a unit that collects the data stream during defined time intervals, transforming it into raw packets. In a next step various control information is added to these raw packets.

These are:

- time position of the last packet received (from output data demultiplexer)

- field strength of the last packet received (from output data demultiplexer)

- packet acknowledge information

- target adress

- capacity requirements

The thus completed raw packets then are fed into the packet buffers, provided with ECC/CRC information and entered into the buffer queue.

The packet buffers receive acknowledge and error information from the output data demultiplexer. They serve to remove packets acknowledged by the subscriber station from the buffer queue. If packets sent out are not acknowledged within a predefined time span they are repeated.

The filling level of the individual buffers is constantly reported to system control. System control therefrom determines the capacity requirements of the individual channels and communicates it to the base station.

The completed packets now are available at the transmit multiplexer. It is completely under control of system control, selecting a packet from the selected packet buffer and feeding it in serialized form into the transmitter at high speed.

4.2.2.3. Output data demultiplexer subscriber station

The block diagram of theoutput data demultiplexer is shown in Figure 38. It gets a - more or less continuous - stream of data packets from the receiver. They are first read into a buffer. From there they are fed into a checking unit checking the packets for errors and correcting them, if required. If this is impossible, they are discarded. Packets not adressed to the local subscriber station are also discarded. Next the adress is extracted and the time of reception is determined. Then various control information is extracted. They are:

- adress information of the received packet (to output data demultiplexer for generating acknowledge information)

- time position of the received packet (to output data demultiplexer, information to be sent back to base station for propagation delay measurement)

- field strength of the received packet (to output data demultiplexer, information to be sent back to base station for beam control of base station transmission beam)

- Acknowledge information (to the packet buffer of the input data multiplexer to remove acknowledged packets)

- status information (to system control)

The remaining "payload information" of the individual packets now is fed into the receive demultiplexer. It in turn feeds them - under control of the adress extraction stage - to the respective output channels.

4.2.2.4. System control subscriber station

System control handles all operational sequences in the system. Its block diagram is shown in Figure 39. In the context of the subscriber station, these are relatively few, in fact providing real time clock, calculating distance, speed and direction towards the base station (satellite), implementing the transmit time slot schedule, controlling beam direction and determining the traffic requirements.

4.2.2.4.1. Central clock and adress cycler

A central unit of system control is the central clock. This is a highly stable quartz crystal based clock generator. It should have a short term stability of 0.1 ppm or better.

The central clock controls the adress cycler which cycles through the adresses of the time slot data register transmission. It is in fact a kind of real time clock that constantly provides system time.

4.2.2.4.2. The time slot data register transmission

The time slot data register transmission controls the transmit multiplexer of the input data multiplexer. It contains the time slot information required for this.

The time slot data register is organized in the form of a list in which the time positions of the start and the end of a transmission are related to a channel identification in the case a subscriber station runs more than one channel. In response to actual system time provided by the adress cycler this register outputs the channel identification belonging to the time slot the adress cycler is pointing to.

The channel identification provided by the time slot data register transmission is directly fed into the transmit multiplexer of the input data multiplexer. The transmit multiplexer thus takes a packet from the selected packet buffer, serializes it and sends it at high speed to the radio set and from there to the respective subscriber station.

The data output by the time slot data register reception serve to check if the incoming packets arrive at exactly the scheduled time positions. Should there be any deviation, a correction value is calculated and sent to the respective subscriber station to enable it to fine tune its time scale.

4.2.2.4.3. The time slot data administration unit transmission

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The time slot data register transmission is controlled by the time slot data administration unit transmission.

This unit receives actualized transmit time window data from the base station and feeds them into the time slot data register transmission.

It also stops transmission if for some reason the time slot window data - which are to arrive at regular intervals - do not arrive as they are to be expected until another time slot window data set can be received. This is crucial to avoid using an outdated timing scheme that could cause interference with other stations.

As, however, the subscriber station and the base station - the latter being a satellite - have a relative movement to each other, which means that the propagation delay varies constantly, the time slot data administration unit transmission receives data concerning this from the orbital data computer. This data is used in order to correct the transmit time positions so that the packets sent out always hit correctly in the assigned receive time slot onboard the base station.

It also obtains deviation information from the base station indicating how precisely the transmitted packets hit into the assigned time slot. This information is used to adjust transmit timing in order to eliminate this deviation.

4.2.2.4.4. Orbital data computer

The orbital data computer obtains Kepler data from the base station and uses them to predict the distance changes between subscriber and base station. From this it calculates the changes in propagation delay. Due to the high speed of orbiting satellites this is required, because propagation delay changes sufficiently even between two packets that without such a measure there would be a severe mismatch between the assigned reception time slot at the base station and the actual arrival of the uplinked packet.

Another task of the orbital data computer is the calculation of the beam direction towards the satellite to track it with the beam steered subscriber station antenna.

4.2.2.4.5. Beam control system

Due to the fact, that the subscriber station may be onboard a vehicle or aircraft or even be used portably, and consequently subscriber station attitude may change any time, a steerable beam antenna is required. Unlike at the base station, it only serves to track one base station, and its steering speed need not be very high.

The beam control system obtains the initial direction information during the login process, during which it is under control of the login unit.

During active communications, the beam control system receives angular position data of the satellite from the orbital data computer and attitude data from the attitude sensor. The angular position data are used to correct beam direction as the satellites moves over the sky. The attitude data are required to steer the antenna beam so that in case of attitude changes the antenna beam keeps being pointed to the base station.

Furthermore the beam cotrol system also does slow dithering much in the same way as the base station to recognize any beam misalignments and to correct them. As only one antenna is used, it is sufficient to do this only for the reception direction, as the transmission direction will automatically be the same.

4.2.2.4.6. Attitude sensor

The attitude sensor serves to determine the attitude of the transmit / receive antenna. This is required in mobile or portable systems where attitude may change any time to keep the antenna beam lobes pointed onto the satellite. It may be of any known design, e. g. gyroscopic, using the Sagnac effect (optical) or the Coriolis effect (mechanical /acoustical). However, as the Coriolis type sensors are easily and cheaply to fabricate and have excellent sensitivity, they may be preferred for cost reasons.

4.2.2.4.7. Traffic demand determination

The traffic demand determination or short demand determination receives data about the filling levels of the individual packet buffers. It determines capacity requirement data for the individual channels and forwards this value to the base station.

The clock signal of the central clock is also used by the output data demultiplexer to determine the time of reception values of the individual packets.

4.2.2.5. RF system subscriber station

The RF system subscriber station is designed similarly as the one of the base station, but has additionally a narrow band mode for login.

4.3. A multistation wireless communications network

The multistation wireless communications network shown in Figure 40 described in the following serves to provide wireless network infrastructure over a wide are with very efficient radio spectrum usage nad a minimum of network routers to be passed in order to transfer information from one node to another. Furthermore it is intended to be very flexible and easily adaptable to varying needs, it can be easily modified and upgraded while staying fully operating.

It is particularly attractive as a backbone solution for beam steered subscriber access systems as already described. particularly in a multi satellite network.

The principal layout of such a system is shown in Figure 19. There are three principal system components used in the network: star transponders, transfer nodes and end nodes.

The central points in the network are the star transponders. These are fully transparent transponders that receive any data sent to them and send them out as they have been received. They also may contain some network management functions that manage network operations in their immediate neighbourhood.

The star transponders in fact are the connecting device connecting the devices around them with each other: in fact, any device connected to the star transponder can receive anything any other device sends out. This allows quasi direct data transfers from any device around the transponder to any other one. There is no principal limitation to what kind or how many devices may use a star transponder. There may even be changes while the system is in full operation.

In order to connect such a cluster of devies arount a star transponder to other such clusters there are the transfer nodes. All traffic that is not local to the cluster is sent to the appropriate transfer node, which hands it over to the other cluster it is connected to. If it is not local there, it is handed over to another appropriate transfer node. This is done until it arrives at its destination in the network.

In order to link a subscriber channel into the network infrastructure there are the end nodes. They put subscriber channels into an appropriate form to be handed over to the network. The network then sees to it that - by proper routing - the channel is connected with the desired target channel provided by another end node in the network.

It is possible to integrate end node functionality into the transition node or into the star transponder. In the following detailed description this has been done. It is, however, optional.

4.3.1. The end node

A block diagram of the end node is shown in Figure 41. It is made up of an input data multiplexer, an output data multiplexer, a system control, a radio transmitter, radio receiver as well as associated diplexer and antenna.

The input data multiplexer funnels a multitude of input data channels together and brings them into a form so that they can be sent out. The processed data then are fed into the transmitter and sent out by the antenna system.

The output data demultiplexer accepts the data received by the receiver and the antenna system, processes them and splits them into the individual output channels.

The system control controls all operating sequences in the base station. It supplies time frame information for transmission, measures round trip delay to the star transponder and back and reports traffic status data to the central node control system.

Transmitter, receiver, diplexer and antenna are largely conventional and without any peculiarities.

4.3.1.1. Input data multiplexer of the end node

The input data multiplexer of the end node appropriately processes the data coming from a plurality of input channels and funnels them together for transmission. Its block diagram is shown in Figure 42.

The data from the input channels first are fed into a unit that collects the data stream during defined time intervals, transforming it into raw packets. Then adress information is added.

The thus completed raw packets then are fed into the packet buffers, provided with ECC/CRC information and entered into the buffer queue.

The packet buffers receive acknowledge and error information from the output data demultiplexer. They serve to remove packets acknowledged by the subscriber station from the buffer queue. If packets sent out are not acknowledged within a predefined time span they are repeated.

The filling level of the individual buffers is constantly reported to system control. System control therefrom determines the capacity requirements of the individual channels and communicates it to the central node control system.

The completed packets now are available at the transmit multiplexer.

To send out control information a separate dedicated channel is used. First, all the control information to be sent out is collected.

This is:

- packet acknowledge information (from output data demultiplexer)

- capacity requirements (from system control)

After having collected all this information the source adress and CRC/ECC information is added. Then the completed packet is fed into the buffer queue and is also available at the transmit multiplexer.

The transmit multiplexer is completely under control of system control. It selects a packet from each packet buffer, serializes it, and feeds it into the transmitter at high speed.

Transmission is done in a packet train manner, that is, they are sent out one after the other, thus using up the entire assigned time slot.

4.3.1.2. Output data demultiplexer of the end node

The block diagram of the output data demultiplexer is shown in Figure 43. It gets a - more or less continuous - stream of data packets from the receiver. They are first read into a buffer. From there they are fed into a checking unit checking the packets for errors and correcting them, if required. If this is impossible, they are discarded. Next the adress is extracted and the time of reception is determined. Then various control information is extracted.

They are:

- source adresses of packets bound for the end node (to input data multiplexer for generating acknowledge information)

- time stamps of packets echoed back by the star transponder (to system control to measure round trip delay time).

- time slot allocation information from node control system (to system control)

- time slot deviation information from node control system (to system control)

- Acknowledge information (to the packet buffer of the input data multiplexer)

The remaining "payload information" of the individual packets now is fed into the receive demultiplexer. It in turn feeds them - under control of the adress extraction stage - to the respective output channels.

4.3.1.3. System control section of end node

The block diagram of system control is shown in Figure 44. It handles all operational sequences in the system. In the context of the subscriber station, these are relatively few, in fact providing real time clock, implementing the transmit time slot schedule, measuring round trip delay time and determining the traffic requirements.

4.3.1.3.1. Central clock and adress cycler

A central unit of system control is the central clock. This is a highly stable quartz crystal based clock generator. It should have a short term stability of 0.1 ppm or better.

The central clock controls the adress cycler which cycles through the adresses of the time slot data register transmission. It is in fact a kind of real time clock that constantly provides system time.

4.3.1.3.2. The time slot data register transmission

The time slot data register transmission controls the transmit multiplexer of the input data multiplexer. It contains the time slot information required for this.

The time slot data register transmission is organized as a list containing the start of the transmit time slot and the lengths of the packets on all channels to be sent out next. When the beginning of the assigned transmission time slot occurs it starts at the first packet buffer and gates out the number of bits equivalent to the length of the packet to be sent out. Having finished this, it proceeds to the next one, until a packet from each buffer has been taken and sent out. Then it stops and waits until the next transmit time slot occurs.

4.3.1.3.3. The time slot data administration unit transmission

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The time slot data register transmission is controlled by the time slot data administration unit transmission.

This unit receives actualized transmit time window data from the node control system and feeds them into the time slot data register transmission.

It also obtains deviation information from the node control system indicating how precisely the transmitted packets hit into the assigned time slot. This information is used to adjust transmit timing in order to eliminate this deviation.

It also cooperates with round trip delay measurement. Round trip delay measurement is responsible for measuring round trip delay of packets sent out nad being re- received. The value obtained in fact is the double propagation delay towards the star transponder plus all the internal delays. As the latter are normally known, propagation delay can be calculated precisely. This value is used to calculate the local transmit time slot from the time slot assigned by the node control system.

Round trip delay measurement further receives time stamped packets from the node control system. This is used to establish a time relationship between the node control system and the local time base. this relationship data is also passed to the time slot data administration.

4.3.1.3.4. Round trip delay measurement

The round trip delay measurement unit receives time stamps and packet source adresses from the output data demultiplexer. It also receives time of transmission information and source adresses of packets that have already been sent out from the time slot administation trannsmission. In comparing these, the round trip delay measurement unit finds the corresponding packets sent out and then received back and subtracts their respective time stamps. The difference is the round trip delay plus the delays of the star transponder and the local system. As those delays are known, the round trip delay can be calculated. Dividing it by two yields the propagation delay to the star transponder.

The round trip delay measurement unit further is provided with the control packet from the central node control system. This packet in itself contains a time stap indicating when it was sent out. Like any other packet, it is also time stamped at reception. Now deducting propagation delay from the reception time stamp, this value and the time stamp provided with the packet can be compared. They directly establish a relationship between the time base of the central node control system and the local system. This relationship information, together with the propagation delay information, is sent to the time slot data administration transmission and serves there to correctly establish the local trannsmit time slot.

4.3.1.3.5. Traffic demand determination

The traffic demand determination or short demand determination receives data about the filling levels of the individual packet buffers. It determines capacity requirement data for the individual channels and forwards this value to the node control system.

4.3.1.3.6. Login sequencer

The login sequencer controls the sequence of events when logging into the system.

This sequence of events is rather simple: the central node control system reserves a login time slot from time to time and announces this fact and its data in the control packets it sends out. Due to the fact that the network will normally be used for fixed terrestrial or inter satellite link purposes, it can be assumed that the location of all units are known. This means that the distance of the end node to its related star transponder is also known. A sufficiently precise value of the propagation delay for login purposes can easily derived from this value. The round trip delay measurement unit uses this value to establish a time base relationship with the node control system's time base. Using these values, demand determination feeds its demand requirement data into the input data multiplexer and time slot data administration transmission calculates the correct login time slot data for transmission. As soon as the node control system receives this request, it allocates a time slot to the new end node. As soon as this request packet is received back at the end node, the round trip delay measurement unit is able to precisely determine propagation delay and consequently the time base relationship with the node control system's time base.

The login process is then finished and normal communications are started.

4.3.2. The transfer node

The transfer node serves to transfer data from one star cluster to another. Its block diagram is shown in Figure 45. It is made up of a link set A connected with antenna A, which links the transfer node to one cluster, link set B, which is connected to antenna B links it to another cluster. Both link sets are connected with a router. The router in fact decides which part of the traffic flow in both clusters is to be transferred to the other side and carries the necessary actions out.

If the router recognizes that packets have a local destination he sends them to the output data demultiplexer, where they are separated into data channels serving as a data pathway to subscribers. On the other hand, data channels from locally connected subscribers are fed into an input data multiplexer to have them packetized and fed into the router. The router then sees to it that they are sent out in the right direction. However, this latter function is not an essential part of the transfer node. A transfer node certainly also can fulfil its basic functions . that is routing traffic from one cluster to another - without having any local connect facilities.

4.3.2.1. Input data multiplexer of the transfer node

The block diagram of the input data multiplexer is shown in Figure 46. Operation of this unit is rather simple. Input data on all channels are collected during constant time intervals, then adress and CRC/ECC information is added and the packets are fed into packet buffers. The transmit multiplexer takes the subsequent packet out of the respective packet buffer and sends it in serialized form to the router. It then proceeds to the next packet buffer, doing the same. All packet buffers are scanned in this way, when all have been scanned, the whole process starts all over again.

4.3.2.2. Output data demultiplexer of the transfer node

The block diagram of the output data demultiplexer of transfer node is shown in Figure 47. It receives a stream of packet from the router. It is first fed into a packet buffer, then the adress is extracted. Then the packets are fed into the receive demultiplexer, which distributes it to the appropriate output channels using the adress information extracted by adress extraction.

4.3.2.3. Link Set of the transfer node

The block diagram of the link set is shown in Figure 48. It is made up of an input data multiplexer, an output data multiplexer, a system control, a radio transmitter, radio receiver as well as associated diplexer and antenna.

The input data unit receives input data from the router and brings them into a form so that they can be sent out. The processed data then are fed into the transmitter and sent out by the antenna system.

The output data unit accepts the data received by the receiver and the antenna system, processes them and forwards them to the router.

The system control controls all operating sequences in the link set. It supplies time frame information for transmission, measures round trip delay to the star transponder and back and reports traffic status data to the central node control system.

Transmitter, receiver, diplexer and antenna are largely conventional and without any peculiarities.

4.3.2.3.1. Input data multiplexer of the link set

The input data multiplexer of the end node appropriately processes the data coming from the router and finally sends them to the transmitter. Its block diagram is shown in Figure 49.

Data from the router is first fed into the input data buffer.

The input data buffer receives acknowledge and error information from the output data unit. They serve to remove packets acknowledged by the subscriber station from the buffer queue. If packets sent out are not acknowledged within a predefined time span they are repeated.

The filling level of the input data buffer is constantly reported to system control. System control therefrom determines the capacity requirements and communicates it to the central node control system.

The packets are now ready to be fed to the transmit cache.

To send out control information a separate dedicated packet is used. First, all the control information to be sent out is collected.

This is:

- packet acknowledge information (from output data demultiplexer)

- capacity requirements (from system control)

After having collected all this information the source adress and CRC/ECC information is added. Then the completed packet is is also available to be sent to the transmit cache, too.

The transmit cache is completely under control of system control. It inputs the control packet and as many other packets as fit into the assigned time slot and forwards it in serial way to the transmitter when the next transmit time slot occurs.

Transmission is done in a packet train manner, that is, they are sent out one after the other, thus using up the entire assigned time slot.

4.3.2.3.2. Output data unit of the link set

The block diagram of the output data unit is shown in figure 50. It gets a - more or less continuous - stream of data packets from the receiver. They are first read into a buffer. From there they are fed into a checking unit checking the packets for errors and correcting them, if required. If this is impossible, they are discarded. Next the adress is extracted and the time of reception is determined. Then various control information is extracted.

They are:

- source adresses of packets bound for the end node (to input data multiplexer for generating acknowledge information)

- time stamps of packets echoed back by the star transponder (to system control to measure round trip delay time).

- time slot allocation information from node control system (to system control)

- time slot deviation information from node control system (to system control)

- source adresses of packets bound for the end node (to input data multiplexer for generating acknowledge information)

- time stamps of packets echoed back by the star transponder (to system control to measure round trip delay time).

- time slot allocation information from node control system (to system control)

- time slot deviation information from node control system (to system control)

- Acknowledge information (to the packet buffer of the input data multiplexer)

The remaining "payload information" of the individual packets now is sent to the router.

4.3.2.3.3. System control section of the link set

The block diagram of system control is shown in Figure 51. It handles all operational sequences in the system. In the context of the subscriber station, these are relatively few, in fact providing real time clock, implementing the transmit time slot schedule, measuring round trip delay time and determining the traffic requirements.

4.3.2.3.3.1 Central clock and adress cycler

A central unit of system control is the central clock. This is a highly stable quartz crystal based and should have a short term stability of 0.1 ppm or better.

The central clock controls the adress cycler which cycles through the adresses of the time slot data register transmission. It is in fact a kind of real time clock that constantly provides system time.

4.3.2.3.3.2. The time slot data register transmission

The time slot data register transmission controls the transmit multiplexer of the input data multiplexer. It contains the time slot information required for this.

The time slot data register transmission is organized as a list containing the start of the transmit time slot and its length. The information about length of the transmit time slot is used to load as many of the packets in the input data buffer into the transmit cache as can be sent out within the assigned time slot. When the beginning of the assigned transmission time slot occurs the number of bits equivalent to the lengths of the packets to be sent out is gated out from the transmit cache. Then the time slot data register transmission stops and waits until the next transmit time slot occurs.

4.3.2.3.3.2. The time slot data administration unit transmission

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The time slot data register transmission is controlled by the time slot data administration unit transmission.

This unit receives actualized transmit time window data from the node control system and feeds them into the time slot data register transmission.

It also obtains deviation information from the node control system indicating how precisely the transmitted packets hit into the assigned time slot. This information is used to adjust transmit timing in order to eliminate this deviation.

It also cooperates with round trip delay measurement. Round trip delay measurement is responsible for measuring round trip delay of packets sent out and being re- received. The value obtained in fact is the double propagation delay towards the star transponder plus all the internal delays. As the latter are normally known, propagation delay can be calculated precisely. This value is used to calculate the local transmit time slot from the time slot assigned by the node control system.

Round trip delay measurement further receives time stamped packets from the node control system. This is used to establish a time relationship between the node control system and the local time base. this relationship data is also passed to the time slot data administration.

4.3.2.3.3.3. Round trip delay measurement

The round trip delay measurement unit receives time stamps and packet source adresses from the output data demultiplexer. It also receives time of transmission information and source adresses of packets that have already been sent out from the time slot administation trannsmission. In comparing these, the round trip delay measurement unit finds the corresponding packets sent out and then received back and subtracts their respective time stamps. The difference is the round trip delay plus the delays of the star transponder and the local system. As those delays are known, the round trip delay can be calculated. Dividing it by two yields the propagation delay to the star transponder.

The round trip delay measurement unit further is provided with the control packet from the central node control system. This packet in itself contains a time stap indicating when it was sent out. Like any other packet, it is also time stamped at reception. Now deducting propagation delay from the reception time stamp, this value and the time stamp provided with the packet can be compared. They directly establish a relationship between the time base of the central node control system and the Dividing it by two yields the propagation delay to the star transponder.

The round trip delay measurement unit further is provided with the control packet from the central node control system. This packet in itself contains a time stap indicating when it was sent out. Like any other packet, it is also time stamped at reception. Now deducting propagation delay from the reception time stamp, this value and the time stamp provided with the packet can be compared. They directly establish a relationship between the time base of the central node control system and the local system. This relationship information, together with the propagation delay information, is sent to the time slot data administration transmission and serves there to correctly establish the local trannsmit time slot.

4.3.2.3.3.4. Traffic demand determination

The traffic demand determination or short demand determination receives data about the filling level of the input data buffer. It determines capacity requirements and forwards this value to the node control system.

4.3.2.3.3.5. Login sequencer

The login sequencer controls the sequence of events when logging into the system.

This sequence of events is rather simple: the central node control system reserves a login time slot from time to time and announces this fact and its data in the control packets it sends out. Due to the fact that the network will normally be used for fixed terrestrial or inter satellite link purposes, it can be assumed that the location of all units are known. This means that the distance of the end node to its related star transponder is also known. A sufficiently precise value of the propagation delay for login purposes can easily derived from this value. The round trip delay measurement unit uses this value to establish a time base relationship with the node control system's time base. Using these values, demand determination feeds its demand requirement data into the input data multiplexer and time slot data administration transmission calculates the correct login time slot data for transmission. As soon as the node control system receives this request, it allocates a time slot to the new end node. As soon as this request packet is received back at the end node, the round trip delay measurement unit is able to precisely determine propagation delay and consequently the time base relationship with the node control system's time base.

The login process is then finished and normal communications are started.

4.3.3. The star transponder

The star transponder is the central link in the communications network being described. Its block diagram is shown in Figure 52. Its main purpose is to retransmit any data it receives in a fully transparent way. It may additionally also be used to link subscriber channels into the network. Furthermore it also hosts conveniently the node control system controlling the sequence of actions of the cluster centered around the star transponder.

The star transponder is made up of an antenna, a diplexer, a transmitter, a receiver, a bit regenerator, a feed in and a feed out tee, an input data multiplexer, an output data multiplexer and the node control system.

The receiver is coupled over a bit regenerator, a feed in and a feed out tee coupled to the transmitter. Receiver and transmitter are coupled over a diplexer to the antenna.

Transmitter, receiver, diplexer, bit regenerator, the feed out and feed in tees and antenna are largely conventional and without any peculiarities.

The input data multiplexer funnels a multitude of input data channels together and brings them into a form so that they can be sent out. The processed data then are fed into the transmitter and sent out by the antenna system.

The output data demultiplexer accepts the data received by the receiver and the antenna system, processes them and splits them into the individual output channels.

Input data multiplexer and output data demultiplexer are facultative, they may be left away when local access is not required. Only the part needed for the node control system has to stay in this case.

The node control system controls all operating sequences in the star transponder as well as in the stations attached to it. It receives all traffic status data from all stations around the star transponder. It also receives login requests. Using all these data it determines the time slot data for all attached stations and broadcasts it. It also monitors all emissions for compliance with the determined schedule. Any deviations are immediately broadcast to notify the respective stations and help them eliminate them.

4.3.3.1. Input data multiplexer

The input data multiplexer of the star transponder appropriately processes the data coming from a plurality of input channels and funnels them together for transmission. Its block diagram is shown in Figure 53.

The data from the input channels first are fed into a unit that collects the data stream during defined time intervals, transforming it into raw packets. Then adress information is added.

The thus completed raw packets then are fed into the packet buffers, provided with ECC/CRC information and entered into the buffer queue.

The packet buffers receive acknowledge and error information from the output data demultiplexer. They serve to remove packets acknowledged by the subscriber station from the buffer queue. If packets sent out are not acknowledged within a predefined time span they are repeated.

The filling level of the individual buffers is constantly reported to the central node control system.

The completed packets now are available at the transmit multiplexer.

To send out control information a separate dedicated channel is used. First, all the control information to be sent out is collected.

This is:

- packet acknowledge information (from output data demultiplexer)

- time slot data for each station connected to the star transponder (from node control system)

- timing deviations of received packets with respect to the assigned time slot (from node control system)

After having collected all this information the source adress and CRC/ECC information is added. Then the completed packet is fed into the buffer queue and is also available at the transmit multiplexer.

The transmit multiplexer is completely under control of system control. It selects a packet from each packet buffer, serializes it, and feeds it into the transmitter at high speed.

Transmission is done in a packet train manner, that is, they are sent out one after the other, thus using up the entire assigned time slot.

4.3.3.2. Output data demultiplexer

The block diagram of the output data demultiplexer is shown in Figure 54. It gets a - more or less continuous - stream of data packets from the receiver. They are first read into a buffer. From there they are fed into a checking unit checking the packets for errors and correcting them, if required. If this is impossible, they are discarded. Next the adress is extracted and the time of reception is determined. Then various control information is extracted.

They are:

- source adresses of packets bound for the star transponder (to input data multiplexer for generating acknowledge information)

- time stamps of packets received (to node control system to compare them with assigned time slots)

- Acknowledge information (to the packet buffer of the input data multiplexer)

The remaining "payload information" of the individual packets now is fed into the receive demultiplexer. It in turn feeds them - under control of the adress extraction stage - to the respective output channels.

4.3.3.3. Node control system

The block diagram of the node control system is shown in Figure 55. Basically it is responsible for managing the time slots of all stations linked to the star transponder. It also monitors how well the actual arrival times of the respective packets correspond to the assigned time slots. If there are any deviations, their sizes and signs are sent out to the respective stations in order to be corrected.

It is certainly easiest to locate the node control system at the star transponder. Locating it at a transfer node or an end node is also possible, it only makes all task associated with timing somewhat more complex.

4.3.3.3.1. Central clock and adress cycler

A central unit of system control is the central clock. This is a highly stable quartz crystal based clock generator. It should have a short term stability of 0.1 ppm or better.

The central clock controls the adress cycler which cycles through the adresses of the time slot data register transmission. It is in fact a kind of real time clock that constantly provides system time.

4.3.3.3.2. The time slot data register transmission

The time slot data register transmission controls the transmit multiplexer of the input data multiplexer. It contains the time slot information required for this.

The time slot data register transmission is organized as a list containing the start of the transmit time slot and the lengths of the packets on all channels to be sent out next. When the beginning of the assigned transmission time slot occurs it starts at the first packet buffer and gates out the number of bits equivalent to the length of the packet to be sent out. Having finished this, it proceeds to the next one, until a packet from each buffer has been taken and sent out. Then it stops and waits until the next transmit time slot occurs.

4.3.3.3.3. The time slot data administration

The time slot data register transmission is controlled by the time slot data administration unit.

The time slot data administration is the central part of the node control system. It receives the traffic status data from all linked station via the output data demultiplexer. It also receives login requests. It determines therefrom a list of time slot data (time positions and durations) and broadcasts them so that all stations linked to the star node receive them and use them.

Figure 56 shows its operation in detail. Explanation starts at top left. There the buffer sizes in the input data demultiplexer are checked. Then the incoming traffic status data is read.

If there are any login requests, the time slot list is checked for available space. If there is available space, a preliminary time slot is assigned. Now the sequence of events has arrived at point E.

If there is no available space, a "no channel free" message is handed over to the input data multiplexer to be sent out. The sequence of events then arrives at point E.

If there are no login requests, the sequence of events arrives at point E directly.

Now a check is performed to find out whether traffic requirements actually have changed. If there is no change, a "no schedule change" message is handed over to the input data multiplexer to be sent out. Then the sequence of events restarts at the beginning.

If, however, there is a change in traffic requirements, the required packet lengths are calculated. They are then all summed up and compared with the available total communications cycle. If the sum is bigger than the total cycle, the packet lengths are readjusted and summed up again. The sum then again is compared to the total cycle, and, if it is still bigger, the packet lengths are readjusted again. This is done until the sum fits into the available cycle.

Now the final list of station versus their respective time slot data is created. The the time slot data register transmission. The remaining data are sent to the input data multiplexer to be broadcast to all stations linked to the star transponder. The new schedule is activated at the next cycle.

From there the sequence of events restarts at the beginning.

4.3.3.3.4. The packet timing monitor unit

The packet timing monitor unit gets all source adresses as well as their time stamps from the output data demultiplexer. It compares the time stamps with the respective time slot data from the time slot data administration. Any differences detected are forwarded to the time slot data administration which in turn sends them to the input data multiplexer to be broadcast to all stations linked to the star transponder to help them eliminate these differences.

4.3.4. Combining end node, transfer node and star transponder
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Comparing the block diagram of a transfer node with that of an end node and that of a star transponder it can be easily seen that the latter units are almost a functional subset of a transfer node. This opens up the possibility to add functionality to a transfer node so that it can be configured to behave as an end node or a star transponder by remote command. This is a definite advantage in networks the geometrical topolgy of which is constantly changing, particularly multi orbit multi satellite networks. this allows in fact to maintain a largely constant network topology despite the fact that individual stations constantly change position to each other.

Using appropriate network control algorithms in such a network, geometrical topology can be effectively largely decoupled from network topology, allowing pseudo static network topologies behaving much in the same way as terrestrial networks.

The above possibility is particularly useful if satellites are deactivated at congestion points, thus allowing a smooth takeover of the functionality of the deactivated satellites by those staying in operation.

Text belonging to Fig. 1

1-1: to system control

1-2: Login communications unit

1-3: Login transmitter

1-4: Login receiver

1-5: Login transmit antenna

1-7 Login receive antenna

Text belonging to Fig. 2

2-1: Login request being received ?

2-2: Time stamp login request packet

2-3: Determine direction from which login packet was received

2-4: Extract subscriber identification from login packet

2-5: Request time slot pair from system control

2-6: Time slot pair available ?

2-7: Enter time slot data into reply packet

2-8: Enter time stamp of reception of login request packet into reply packet

2-9: Enter time of transmission of reply packet into reply packet

2-10: Send reply packet

2-11: Enter "no channel available" message into reply packet

Text belonging to Fig. 3

3-1: input data channels

3-2: output data channels

3-3: input data multiplexer

3-4: output data multiplexer

3-5: System control

3-6: Transmitter

3-7: Receiver

3-8: Beam control transmission

3-9: Beam control reception

3-10: Transmit antenna system

3-11: Receive antenna system

3-12: to Login unit

Text belonging to Fig. 4

4-1: Channel 1

4-2: Channel N

4-3: collect input data during constant time intervals

4-4: Add control data

4-5: packet buffer

4-6: Transmit multiplexer

4-7: from output data demultiplexer

4-8: from output data demultiplexer

4-9: buffer size to system control

4-10 from system control (transmit scheduler)

4-11 from system control (transmit scheduler)

4-12: to transmitter

Text belonging to Fig. 5

5-1: from receiver

5-2: packet buffer

5-3: CRC/ECC forward only good packets

5-4: adress extraction/compare with scheduler data

5-5: extract control information

5-6: Receive Demultiplexer

5-7: Channel 1

5-8: Channel N

5-9: to input data multiplexer/packet buffer

5-10: to system control

5-11: from system control

5-12: to system control

Text belonging to Fig. 6

6-1: from input data multiplexer: buffer size

6-2: to transmit multiplexer

6-3: from output data demultiplexer: field strength at subscriber station

6-4: to output data demultiplexer

6-5: control data from output data demultiplexer

6-6: from output data demultiplexer: field strength at receiver

6-7: time slot data register transmission

6-8: Adress cycler

6-9: Central timer unit

6-10: time slot data register reception

6-11: propagation delay processing

6-12: time slot data administration transmission

6-13: transmit/receive collision avoidance at subscriber station

6-14: time slot data administration reception

6-15 time slot information at subscriber station to input data multiplexer

6-16: to input data multiplexer: control information

6-17: from output data demultiplexer: status data from subscriber station

6-18: Beam steering data register transmission

6-19: Dither control transmission

6-20: Dither control reception

6-21: Beam steering data register reception

6-22: to beam control transmission

6-23: to beam control reception

6-24: from/to login communications unit

6-25: from/to login communications unit

Text belonging to Fig. 7

7-1: calculate required packet lengths

7-2: Sum up all packet lengths and compare with available total cycle

7-3: Does sum exceed total cycle ?

7-4: Readjust packet lengths and sum up again

7-5: Create list of subscriber stations versus time slot data

7-6: Have transmit/receive avoidance at subscriber station check list

7-7: Any transmit/receive collisions at subscriber station detected ?

7-8: Change sequence in list as instructed

7-9: Send list to time slot data register transmission

7-10: Send list to beam steering data register transmission

7-11: Activate new transmission schedule at next cycle

7-12: Check packet buffer sizes in input data multiplexer

7-13: Any login requests ?

7-14: Change in traffic requirements ?

7-15: Check schedule list for available space

7-16: Space available ?

7-17: Return "no channel free" message to login unit

7-18: Do preliminary assignment ofr transmit time slot

Text belonging to Fig. 8

8-1: calculate required packet lengths

8-2: Sum up all packet lengths and compare with available total cycle

8-3: Does sum exceed total cycle ?

8-4: Readjust packet lengths and sum up again

8-5: Create list of subscriber stations versus time slot data

8-6: Have transmit/receive avoidance at subscriber station check list

8-7: Any transmit/receive collisions at subscriber station detected ?

8-8: Change sequence in list as instructed

8-9: Has there been a successful login request ?

8-10: Send receive time slot data to login unit

8-11: Send list to input data multiplexer to send data to subscriber stations

8-12: Send list to time slot data register reception

8-13: Send list to beam steering data register reception

8-14: Activate new reception schedule at next cycle

8-15: Check incoming status data

8-16: Any login requests ?

8-17: Change in traffic requirements ?

8-18: Check schedule list for available space

8-19: Space available ?

8-20: Return "no channel free" message to login unit

8-21: Do preliminary assignment of receive time slot

Text belonging to Fig. 9

9-1: transmit/receive collision check at subscriber station requested ?

9-2: Calculate list of arrival time slots of packets at subscriber station

9-3: Calculate list of transmission time slots of packets at subscriber station

9-4: Check lists for overlaps between arrival and transmission time slots

9-5: Overlap detected ?

9-6: Rearrange lists in order to remove overlaps

9-7: Have lists been rearranged ?

9-8: Inform time slot administration transmission that no collisions have been detected

9-9: Inform time slot administration reception that no collisions have been detected

9-10: Instruct time slot administration transmission how to rearrange schedule list

9-11: Instruct time slot administration reception how to rearrange schedule list

Text belonging to Fig. 10

10-1: Subscriber station to be accessed ?

10-2: Is cycle count > 2 ?

10-3: Set cycle count = 0

10-4: Read field strength values from dither table

10-5: Calculate deviation of beam heading from correct value

10-6: Correct direction value in beam steering data register

10-7: Read dither value for cycle count from dither table

10-8: Add dither value to direction value provided by beam steering data register

10-9: Set beam to calculated value

10-10: Get associated field strength value

10-11: Store field strength value in dither table

10-12: Cycle count = Cycle count + 1

Text belonging to Fig. 11

11-1: DRO

11-2: Buffer amplifier

11-3: from transmit multiplexer: key control

11-4: Keying stage

11-5: from transmit multiplexer: data

11-6: QPSK modulator

11-7: Power amplifier

11-8: Steerable beam antenna transmission

11-9: field strength to output data demultiplexer

11-10: to output data demultiplexer

11-11: QPSK demodulator

11-12: IF filter/amplifier

11-13: Mixer

11-14 DRO

11-15 Preamplifier

11-16: Steerable beam antenna reception

Text belonging to Fig. 12

12-1: Data from subscribers

12-2: Input data multiplexer

12-3: Transmitter

12-4: Transmit/Receive switch

12-5: Antenna

12-6: Data to subscribers

12-7: Output data demultiplexer

12-8: Receiver

12-9: System control unit

12-10: Login control unit

Text belonging to Fig. 13

13-1: Send communications request packet

13-2: Wait for reply packet

13-3: Reply packet received within wait time ?

13-4: Time stamp reply packet

13-5: Does reply packet contain "no channel available" message ?

13-6: Extract time slot data from reply packet

13-7: Extract time of reception of communications request packet at base station from reply packet

13-8: Extract time of transmission of reply packet at base station from reply packet

13-9: Calculate propagation delay

13-10: Establish relationship between base station and local time base

13-11: Start active communications and pass control to system control

13-12: Send short packet at center of assigned time slot

13-13: Wait for reply from base station

13-14: Extract time slot deviation information from reply packet

13-15: Correct time base relationship

13-16: Start final communications

Text belonging to Fig. 14

14-1: Channel 1

14-2: Channel M

14-3: collect input data during constant time intervals

14-4: Add control data

14-5: packet buffer

14-6: Transmit multiplexer

14-7: from output data demultiplexer

14-8: from output data demultiplexer

14-9: buffer size to system control

14-10 from system control (transmit scheduler)

14-11 from system control (transmit scheduler)

14-12: to transmitter

Text belonging to Fig. 15

15-1: from receiver

15-2: packet buffer

15-3: CRC/ECC forward only good packets

15-4: adress extraction/compare with scheduler data

15-5: extract control information

15-6: Receive Demultiplexer

15-7: Channel 1

15-8: Channel M

15-9: to input data multiplexer/packet buffer

15-10: to system control

15-11: from system control

15-12: to system control

Text belonging to Fig. 16

15-1: to the transmit multiplexer

16-2: time slot data register transmission

16-3: Adress cycler

16-4: Central timer unit

16-5: Time slot data administration transmission

16-6: from output data demultiplexer: time slot allocation deviation information

16-7: from/to login control

16-8: input data multiplexer buffer size

16-9: demand determination

16-10: input data multiplexer control data

Text belonging to Fig. 17

17-1: to system control

17-2: PN - sequencer

17-3: transmitter

17-4: Diplexer

17-5: Beam steerable antenna system

17-6: Login communications unit

17-7: Beam steering unit

17-8: PN - correlator

17-9: Receiver

17-10: Doppler compensator

17-11: from system control: attitude data

17-12: from system control: orbital data

Text belonging to Fig. 18

18-1: Base station (e. g. satellite)

18-2: Login/Search antenna

Text belonging to Fig. 19

19-1: Beam direction changed ?

19-2: Read new beam direction

19-3: Calculate slant speed vector

19-4: Determine latitude of point where antenna beam hits earth surface

19-5: Calculate earth rotation speed vector at hit point

19-6: Determine sum speed vector

19-7: Calculate doppler shift

19-8: Set login radio set correspondingly

Text belonging to Fig. 20

20-1: Login signal detected ?

20-2: Proceed to next cell

20-3: Time stamp received packet

20-4: Extract time of transmission of packet (provided by subscriber station)

20-5: Extract station identification from packet

20-6: Transmission over ?

20-7: Enter received identification code into reply packet

20-8: Enter time of transmission of received login request packet into reply packet

20-9: Enter time of reception of received login request packet into reply packet

20-10: Enter origin of PN - signal into reply packet

20-11 Enter time of transmission of reply packet into reply packet

20-12: Send reply packet

20-13: Start PN signal

20-14: Wait for reply signal from subscriber station

20-15: Reply signal within predetermined time span ?

20-16: Extract coarse round trip delay data

20-17: Preset PN - correlator

20-18: Lock PN - correlator onto PN - signal from subscriber station

20-19: Read PN - origin offset data

20-20: Calculate exact round trip delay data

20-21: Dither beam direction

20-22: Determine exact beam heading

20-23: Request time slot pair from system control

20-24: Time slot pair available ?

20-25: Send "no channel available" message to subscriber station

20-26: Enter time slot data into second reply packet

20-27: Enter exact round trip delay data into second reply packet

20-28: Send second reply packet

20-29: End login communications

20-30: Wait for predetermined time for more login calls

20-31: Any more login calls ?

Text belonging to Fig. 21

21-1: Interlink antenna system

21-2: Interlink system

21-3: input data multiplexer

21-4: Transmitter

21-5: Antenna system

21-6: Onboard switching system

21-7: output data demultiplexer

21-8: Receiver

21-9: Active/standby control

21-10: System control

21-11: Beam control transmission

21-12: Beam control reception

21-13: Active/standby signal to all onboard units

21-14: to Login control

Text belonging to Fig. 22

22-1: Channel 1

22-2: Channel N

22-3: collect input data during constant time intervals

22-4: Add control data

22-5: packet buffer

22-6: Transmit multiplexer

22-7: from output data demultiplexer

22-8: from output data demultiplexer

22-9: buffer size to system control

22-10 from system control (transmit scheduler)

22-11 from system control (transmit scheduler)

22-12: to transmitter

Text belonging to Fig. 23

23-1: from receiver

23-2: packet buffer

23-3: CRC/ECC forward only good packets

23-4: adress extraction/compare with scheduler data

23-5: extract control information

23-6: Receive Demultiplexer

23-7: Channel 1

23-8: Channel N

23-9: to input data multiplexer/packet buffer

23-10: to system control

23-11: from system control

23-12: to system control

Text belonging to Fig. 24

24-1: from input data multiplexer: buffer size

24-2: to transmit multiplexer

24-3: from output data demultiplexer: field strength at subscriber station

24-4: to output data demultiplexer

24-5: control data from output data demultiplexer

24-6: from output data demultiplexer: field strength at receiver

24-7: time slot data register transmission

24-8: Adress cycler

24-9: Central timer unit

24-10: time slot data register reception

24-11: propagation delay processing

24-12: from output data demultiplexer: status data from subscriber station

24-13: time slot data administration transmission

24-14: transmit/receive collision avoidance at subscriber station

24-15: Orbital data computing unit

24-16: time slot data administration reception

24-17: time slot information at subscriber station to input data multiplexer

24-18: to input data multiplexer: control information

24-19: Beam steering data register transmission

24-20: Dither control transmission

24-21: Attitude sensor

24-22: Dither control reception

24-23: Beam steering data register reception

24-24: to beam control transmission

24-25: to Login control

24-26: to Login control

24-27: to beam control reception

24-28: from/to login communications unit

24-29: from/to login communications unit

Text belonging to Fig. 25

25-1: calculate required packet lengths

25-2: Sum up all packet lengths and compare with available total cycle

25-3: Does sum exceed total cycle ?

25-4: Readjust packet lengths and sum up again

25-5: Create list of subscriber stations versus time slot data

25-6: Have transmit/receive avoidance at subscriber station check list

25-7: Any transmit/receive collisions at subscriber station detected ?

25-8: Change sequence in list as instructed

25-9: Send list to time slot data register transmission

25-10: Send list to beam steering data register transmission

25-11: Activate new transmission schedule at next cycle

25-12: Check packet buffer sizes in input data multiplexer

25-13: Any login requests ?

25-14: Change in traffic requirements ?

25-15: Check schedule list for available space

25-16: Space available ?

25-17: Do preliminary assignment of transmit time slot

25-18: Return "no channel free" message to login unit

Text belonging to Fig. 26

26-1: calculate required packet lengths

26-2: Sum up all packet lengths and compare with available total cycle

26-3: Does sum exceed total cycle ?

26-4: Readjust packet lengths and sum up again

26-5: Create list of subscriber stations versus time slot data

26-6: Have transmit/receive avoidance at subscriber station check list

26-7: Any transmit/receive collisions at subscriber station detected ?

26-8: Change sequence in list as instructed

26-9: Has there been a successful login request ?

26-10: Send receive time slot data to login unit

26-11: Send list to input data multiplexer to send data to subscriber stations

26-12: Send list to time slot data register reception

26-13: Send list to beam steering data register reception

26-14: Activate new reception schedule at next cycle

26-15: Check incoming status data

26-16: Any login requests ?

26-17: Check schedule list for available space

26-18: Space available ?

26-19: Return "no channel free" message to login unit

26-20: Do preliminary assignment of receive time slot

Text belonging to Fig. 27

27-1: transmit/receive collision check at subscriber station requested ?

27-2: Calculate list of arrival time slots of packets at subscriber station

27-3: Calculate list of transmission time slots of packets at subscriber station

27-4: Calculate list of time slot time position "wanderings" using orbital data

27-5: Check lists for overlaps between arrival and transmission time slots

27-6: Overlap detected ?

27-7: Rearrange lists in order to remove overlaps

27-8: Have lists been rearranged ?

27-9: Inform time slot administration transmission that no collisions have been detected

27-10: Inform time slot administration reception that no collisions have been detected

27-11: Instruct time slot administration transmission how to rearrange schedule list

27-12: Instruct time slot administration reception how to rearrange schedule list

Text belonging to Fig. 28

28-1: Subscriber station to be accessed ?

28-2: Is cycle count > 2 ?

28-3: Set cycle count = 0

28-4: Read field strength values from dither table

28-5: Calculate deviation of beam heading from correct value

28-6: Correct direction value in beam steering data register

28-7: Read dither value for cycle count from dither table

28-8: Add dither value to direction value provided by beam steering data register

28-9: Set beam to calculated value

28-10: Get associated field strength value

28-11: Store field strength value in dither table

28-12: Cycle count = Cycle count + 1

Text belonging to Fig. 29

29-1: DRO

29-2: Buffer amplifier

29-3: from transmit multiplexer: key control

29-4: Keying stage

29-5: from transmit multiplexer: data

29-6: QPSK modulator

29-7: Power amplifier

29-8: Diplexer

29-9: Steerable dual beam antenna

29-10: field strength to system control

29-11: to output data demultiplexer

29-12: QPSK demodulator

29-13: IF filter/amplifier

29-14: Mixer

29-15: DRO

29-16: Preamplifier

Text belonging to Fig. 32

32-1: Determine present net topology

32-2: Parametrize topology with area requirements

32-3: Determine present loading situation

32-4: Determine areas where station density is above minimum

32-5: Determine most closeup stations in an area

32-6: Does taking away one closeup stations leave all distances below maximum ?

32-7: Does taking away one closeup stations leave traffic loading below maximum ?

32-8: Deactivate station and restructure local network

32-9: Go to next area

32-10: All areas done ?

Text belonging to Fig. 33

33-1: Monitor areas with standby satellites in them

33-2: Parametrize topology with area requirements

33-3: Analyze distance situation around standby satellites

33-4: Any distance larger than upper limit ?

33-5: Activate standby satellite

33-6: Rearrange network around it

33-7: Proceed to next area

Text belonging to Fig. 34

34-1: Data from subscribers

34-2: Input data multiplexer

34-3: Transmitter

34-4: Transmit/Receive switch

34-5: Antenna system

34-6: Data to subscribers

34-7: Output data demultiplexer

34-8: Receiver

34-9: System control unit

34-10: Login control unit

34-11: Beam control

Text belonging to Fig. 35

35-1: to/from transmitter

35-2: from receiver

35-3: to/from system control

35-4: Login control system

35-5: PN Generator

35-6: PN correlator

Text belonging to Fig. 36

36-1: Login signal detected ?

36-2: Proceed to next cell

36-3: Activate transmitter

36-4: Send station identification and time stamp at each instance of cyclical transmission

36-5: Stop transmission after predetermined time

36-6: Signal from base station detected within predetermined time ?

36-7: Has packet local destination ?

36-8: Wait for end of login process with station being dealt with

36-9: End signal detected within predetermined time within predetermined time ?

36-10: Time stamp received reply packet

36-11: Extract time of transmission of received login request packet

36-12: Extract time of reception of received login packet

36-13: Extract time of transmission of reply packet

36-14: Extract PN - origin time stamp

36-15: Calculate coarse round trip delay time

36-16: Preset PN - correlator

36-17: Lock onto PN signal

36-18: Synchronize local PN - generator with received PN - signal

36-19: Base station transmission terminated ?

36-20: Start PN modulated transmission

36-21: Insert coarse round trip delay data into packet

36-22: Send packet

36-23: Answer signal from base station within predetermined time ?

36-24: Does reply packet contain "no channel available" message ?

36-25: Extract exact round trip delay data

36-26: extract assigned time slot data

36-27: Establish relationship between local and base station time base

36-28: Start active communications and pass control to system control

36-29: Send short packet at center of assigned time slot

36-30: Wait for reply from base station

36-31: Extract time slot deviation information from reply packet

36-32: Correct time base relationship

36-33: Start final communications

Text belonging to Fig. 37

37-1: Channel 1

37-2: Channel M

37-3: collect input data during constant time intervals

37-4: Add control data

37-5: packet buffer

37-6: Transmit multiplexer

37-7: from output data demultiplexer

37-8: from output data demultiplexer

37-9: buffer size to system control

37-10 from system control (transmit scheduler)

37-11 from system control (transmit scheduler)

37-12: to transmitter

Text belonging to Fig. 38

38-1: from receiver

38-2: packet buffer

38-3: CRC/ECC forward only good packets

38-4: adress extraction/matching time stamping

38-5: extraction of control information

38-6: Receive Demultiplexer

38-7: Channel 1

38-8: Channel N

38-9: to input data multiplexer/packet buffer

38-10: to system control

38-11: from system control

38-12: to system control

Text belonging to Fig. 39

39-1: to the transmit multiplexer

39-2: time slot data register transmission

39-3: Adress cycler

39-4: Central timer unit

39-5: input data multiplexer buffer size

39-6: demand determination

39-7: input data multiplexer status data

39-8: from output data demultiplexer: time slot allocation deviation information

39-9: Time slot data administration transmission

39-10: orbital data computer

39-11: Beam control system

39-12: Attitude sensor

39-13: from/to login control

39-14: from output data demultiplexer: Kepler data

39-15: to beam control

39-16: from login control: beam heading instructions

Text belonging to Fig. 40

ST: star transponder

EN: end node

TN: transfer node

Text belonging to Fig. 41

41-1: Data from subscribers

41-2: Input data multiplexer

41-3: Transmitter

41-4: Diplexer

41-5: Antenna

41-6: Data to subscribers

41-7: Output data demultiplexer

41-8: Receiver

41-9: System control unit

Text belonging to Fig. 42

42-1: collect control data

42-2: Add CRC/ECC, source adress

42-3: packet buffer

42-4: Channel 1

42-5: collect input data during constant time intervals

42-6: Add CRC/ECC, adresses

42-7: packet buffer

42-8: Transmit multiplexer

42-9: to transmitter

42-10: Channel M

42-11: from output data demultiplexer

42-12: from output data demultiplexer

42-13: buffer size to system control

42-14: from system control (transmit scheduler)

42-15 from system control (transmit scheduler)

Text belonging to Fig. 43

43-1: from receiver

43-2: packet buffer

43-3: CRC/ECC forward only good packets

43-4: adress extraction/time stamping

43-5: Extraction of control information

43-6: Receive Demultiplexer

43-7: Channel 1

43-8: Channel M

43-9: to input data multiplexer/packet buffer

43-10: to system control

43-11: to system control/input data multiplexer

43-12: to system control

Text belonging to Fig. 44

44-1: to the transmit multiplexer

44-2: time slot data register transmission

44-3: Adress cycler

44-4: Central timer unit

44-5: input data multiplexer: buffer sizes

44-6: demand determination

44-7: input data multiplexer: control data

44-8: Time slot data administration transmission

44-9: Round trip delay measurement

44-10: Login sequencer

44-11: from output data demultiplexer: time slot allocation, deviation information

44-12: from output data demultiplexer: time stamps, packet source adresses

Text belonging to Fig. 45

45-1: Antenna A

45-2: Antenna B

45-3: Link set A

45-4: Router

45-5: Link set B

45-6: Data from subscribers

45-7: Input data multiplexer

45-8: Data to subscribers

45-9: Output data demultiplexer

Text belonging to Fig. 46

46-1: Channel 1

46-2: Channel M

46-3: collect input data during constant time intervals

46-4: Add CRC/ECC, adresses

46-5: packet buffer

46-6: Transmit multiplexer

46-7: to router

Text belonging to Fig. 47

47-1: from router

47-2: packet buffer

47-3: Adress extraction

47-4: Receive demultiplexer

47-5: Channel 1

47-6: Channel M

Text belonging to Fig. 48

48-1: Data from router

48-2: Input data unit

48-3: Transmitter

48-4: Antenna

48-5: Data to router

48-6: Output data unit

48-7: Receiver

48-8: Diplexer

48-9: System control

Text belonging to Fig. 49

49-1: Data from router

49-2: to system control: buffer size

49-3: from output data unit: Acknowledge receive

49-4: Input data buffer

49-5: Add control packet

49-6: Transmit cache

49-7: to transmitter

49-8: from output data unit: Acknowledge transmit

49-9: from system control: status

49-10: from system control (transmit schedule)

Text belonging to Fig. 50

50-1: from receiver

50-2: packet buffer

50-3: CRC/ECC forward only good packets

50-4: adress extraction/time stamping

50-5: to input data unit/input data buffer

50-6: Extraction of control packet

50-7: data to router

50-8: to system control

50-9: to system control

50-10: to system control

Text belonging to Fig. 51

51-1: to the transmit cache

51-2: input data unit: buffer size

51-3: input data unit: control data

51-4: time slot data register transmission

51-5: Adress cycler

51-6: Central timer unit

51-7: demand determination

51-8: Time slot data administration transmission

51-9: Round trip delay measurement

51-10: Login sequencer

51-11: from output data unit

51-12: from output data unit: time stamps, packet source adresses

Text belonging to Fig. 52

52-1: Data from subscribers

52-2: Input data multiplexer

52-3: Feed in tee

52-4: Transmitter

52-5: Diplexer

52-6: Antenna

52-7: Data to subscribers

52-8: Output data demultiplexer

52-9: Feed out tee

52-10: Bitregenerator

52-11: Receiver

52-12: Node control system

Text belonging to Fig. 53

53-1: collect control data

53-2: packet buffer

53-3: Channel 1

53-4: collect input data during constant time intervals

53-5: Add CRC/ECC, adresses

53-6: packet buffer

53-7: Transmit multiplexer

53-8: to transmitter

53-9: Channel M

53-10: from output data demultiplexer

53-11: from output data demultiplexer

53-12: buffer size to node control

53-13: from node control

53-14 from node control

Text belonging to Fig. 54

54-1: from receiver

54-2: packet buffer

54-3: CRC/ECC forward only good packets

54-4: adress extraction/time stamping

54-5: Extraction of control information

54-6: Receive Demultiplexer

54-7: Channel 1

54-8: Channel M

54-9: to input data multiplexer/packet buffer

54-10: to node control system

54-11: to node control system

54-12: to node control system

Text belonging to Fig. 55

55-1: to transmit multiplexer

55-2: from output data demultiplexer

55-3: time slot data register transmission

55-4: Adress cycler

55-5: Central timer unit

55-6: time slot data administration

55-7: packet timing monitor unit

55-8: from input data multiplexer: buffer size

55-9: to input data multiplexer: control data

55-10: from output data demultiplexer: traffic status data, login requests

Text belonging to Fig. 56

56-1: check packet buffer sizes in input data multiplexer

56-2: Check incoming status data

56-3: Any login requests ?

56-4: Check schedule list for available space

56-5: Space available ?

56-6: Do preliminary assignment of time slot

56-7: Change in traffic requirements ?

56-8: Calculate required packet lengths

56-9: Sum up all packet lengths and compare with available total cycle

56-10: Does sum exceed total cycle ?

56-11: Readjust packet lengths and sum up again

56-12: Return "no channel free" message to input data multiplexer

56-13: Return "no schedule change" message to input data multiplexer

56-14: Create list of stations versus time slot data

56-15: Send local data to time slot data register transmission

56-16: Send list to input data multiplexer to broadcast data

56-17: Activate new scheme at next cycle

5. Claims:

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1. A communications system in which a base station serves a plurality of user stations, the base station being equipped with a steerable beam antenna being controlled by a beam steering control unit, whereby, when the base station has to send information to one of the ground stations, it directs the beam of its transmit antenna towards said user station, sends the information to be sent, then determines the next user station to which information has to be sent, sends the information, then determines again the next one, and so forth, until the information to be sent to all the ground stations has been transferred.

2. A communications system in which a base station serves a plurality of user stations, the base station being equipped with a steerable beam antenna being controlled by a beam steering control unit, whereby, when one of the user stations has to send information to said base station, it directs the beam of its receive antenna towards said user station at a predefined time, receives the information having been sent by said user station, then determines the next user station from which information has to be received and the next predefined time, receives the information, then determines again the next one, and so forth, until the information having been sent from all the ground stations has been gathered.

3. A communications system combining the fuctions of claim 1 and claim 2.

4. A communications system according to any of the preceding claims, in which the functions of the beam

steerable transmit and receive antenna system are integrated into one unit.

5. A communications system according to any of the preceding claims in which the base station is a satellite and the user stations are portable or mobile end user units.

6. A communications system according to any of the preceding claims in which the information transferred is digital.

7. A communications system according to any of the preceding claims in which the information transferred is packetized.

8. A communications system according to any of the preceding claims in which there is a plurality of base stations interconnected to form a network, each of said base stations serving a plurality of user stations.

9. A communications system in which the base station determines a time schedule for the user stations according to which they have to send their information, furthermore measures the round trip delay to each of the user stations, and determines the time, at which the transmission of a particular user station arrives at the base station, by adding half of the round trip delay time to the scheduled time at which said ground station sends, and determines said time schedule for the user stations in a way that the information from the user stations arrives in a sequence at the base stations, there being neither any overlaps nor excessive gaps between the individual chunks of information received.

10. A communications system according to claim 9 in which the transmit time schedule for the user stations is checked whether an overlap of a transmission and a reception period at any of the user stations occurs, and, if this is determined, the sequence in which information is sent to the individual user stations and / or the sequence in which said user stations are to transmit their information is permutated in a way that no such overlaps occur.

11. A communications system according to any of the preceding claims in which the clock of the base station and the clocks of the user stations are all synchronized.

12. A communications system according to claim 10 in which the synchronization is achieved by sending a time stamp and the measured value of the round trip delay from the base station to each of the user stations, so that each of the user stations can calculate the time onboard the base station and sets its own clock accordingly.

13. A communications system according to any of the preceding claims 1 to 9 in which the direction of each of the user stations with respect to the base station is determined by intentionally slightly mispointing the beam to each of said user stations in a first direction, measuring the received field strength at the receiver, next time the same user station is pointed to mispointing the beam in a second direction, again taking the received field strength at the receiver, again next time the same user station is pointed to mispointing the beam in a third direction, once again taking the received field strength at the receiver, then comparing the three values of field strength together and determining from said comparision the exact direction to the respective user station.

14. A communications system according to claim 13 in which the determination of the direction towards each of the user stations is done using more than three steps.

15. A base station / user station communications system with a high speed TDMA main communications unit for high speed communications, being equipped with a login system in which the base station is equipped with a wide angle login antenna.

16. A system according to claim 15 in which the base station waits for login requests from user stations.

17. A system according to claim 16 in which the user stations send login request packets with a time stamp and their identification code.

18. A system according any of the claims 15, 16 or 17, where the signal from the user station is time stamped upon reception at the base station.

19. A system according to claims 17 or 18, in which the base station requests a time slot pair at the main communications unit.

20. A system according to claim 19, in which the base station sends the time slot data, the time stamp of reception of the request message and the time stamp of transmission of the reply message to the user station.

21. A system according to claim 20, in which the base station ends login communication after sending the reply message and hands over to the main communications unit.

22. A system according to claims 20 or 21, in which the

user station uses the time stamp data from the reply message to calculate the propagation delay to the base station.

23. A system according to claim 22, in which the user station uses the propagation delay value and the send time stamp of the reply message to synchronize its internal clock system to that of the base station.

24. A system according to claim 23, in which the user station sends a small packet as a first packet in the center of its assigned send time slot.

25. A system according to claim 24, in which the base station main communications unit reports back the exact position of the narrow packet within the assigned time slot.

26. A system according to claim 25, in which the user station uses this value to synchronize its internal clock system to that of the base station more precisely.

27. A base station / user station system with a base station for communications with user stations, being equipped with a system for providing a login capability with a steerable beam antenna, scanning its service area for signals from user stations.

28. A base station / user station system with at least one user station being equipped with a system for providing a login capability with a steerable beam antenna, scanning the area inside a predefined angle for signals from base stations.

29. A system according to any of the preceding claims 27 or

28 in which the base station login system constantly puts out a signal in to allow a user station to detect the presence of a satellite.

30. A system according to claim 29, in which the user station upon receipt of a base station signal stops scanning and sends a reply signal for at least the time span required by the base station to scan its service area.

31. A system according to claim 30, where the signal from the user station contains its identification code, which is constantly repeated as long as the transmission lasts, and associated time stamps attached to each instance of an identification code to identify the time at which it occured.

32. A system according to claim 31, in which the base station extracts identification code and time stamps from the user station signal, time stamps the received signal itself and sends this data back to the user station, thereby also sending back a timestamp of the time of transmission.

33. A system according to claim 32, in which the signal back to the ground station is superimposed with a PN signal and the time of origin of the signal is included in the signal back to the user station.

34. A system according to claims 32 or 33, where the user station determines the coarse round trip delay time from the data received from the base station.

35. A system according to claims 32, 33, or 34, where the user station sends a further answer to the satellite, containing round trip delay information.

36. A system according to claim 35, where a further PN signal is superimposed on the further answer signal to the satellite, and said further answer signal also contains the origin time of said further PN signal as well as the time offset between said received PN signal and said further PN signal.

37. A system according to claim 36, where the base station receives the data from the user station coming from said further answer signal, determines the time origin from said further PN signal and therefrom determines exact round trip delay time.

38. A system according to claim 37, where said data are sent to the main communications system for preparation of main communications.

39. A system according to claim 38, where the main communications unit determines time slots for inserting the station logging in into the communications queue, and said queuing information together with the exact round trip delay data are sent down to the ground station.

40. A system according to claim 39, where the user station upon receipt of the queuing data proceeds towards main communications and terminates the login communication.

41. A digital wireless communications network, consisting of a central transponder and a number of nodes, communicating with each other by means of said transponder.

42. A digital wireless communications network according to claim 1, in which at least one node is equipped with a routing device and at least one other wireless system,

allowing said node to communicate at the same time with at least another network of the type of claim 1.

43. A network according to any of the claims 41 or 42, in which there exists a node management unit controlling the exact time points and time spans of transmission of all nodes in the network in order to eliminate collisions caused by the propagation delay dead times in the network.

44. A network according to claim 43 in which the node in the network time their transmissions in a way that the transmissions arrive at the central transponder one after the other in a sequence, until transmissions from all nodes in the network have been received, after which the cycle is repeated again.

45. A network according to claim 43 or 44, in which the transmission time spans of the nodes are controlled by the node management unit in a way that each node gets a share of the total available transmission time according to the traffic it has to handle.

46. A network according to claim 45, in which each node informs the node management unit constantly about the amount of traffic it has to handle.

47. A network according to claim 46, incorporating said information about the amount of traffic a node has to handle is incorporated in the traffic packets it sends out.

48. A network according to claim 46, incorporating said information about the amount of traffic a node has to handle is incorporated in separate status packets.

49. A network according to any of the claims 43 to 48, in

which the the node management unit sends control packets containing the time schedule for each node at predefined regular intervals.

50. A network according to claim 49, in which the control information sent by the node management unit is valid for a predefined number of transmission cycles, after which transmission operation is stopped if no new control information is received.

51. A network according to claim 50, in which operation is resumed when new control information is received.

52. A network according to claims 50 or 51, whereby the control packets sent by the node management unit incorporate the time after which the new instructions are to go into effect.

53. A network according to claims 50 to 52, whereby the control packets sent by the node management unit incorporate length of the next control cycle.

54. A satellite communications network made up of a plurality of orbits with intersecting orbital planes, in which satellites are deactivated when the distances between the remaining active satellites remain withing predefined limits, and where said deactivated satellites are reactivated when said distances do not remain within said predefined limits any more.

55. A satellite network according to claim 54, where the deactivation process serves to save onboard power.

56. A satellite network according to any of the claims 54 or 55, in which said predefined distances are set according

to end user density.

57. A satellite network according to any of the claims 54 to 56, in which said predefined distances are set according to terrain flatness.

58. A satellite network according to any of the claims 54 to 57, where said predefined distances are determined by a grazing angle limit determined for each type of area.

59. A satellite network according to any of the claims 54 to 58, where a criterion for said activation / deactivation operation is flatness.

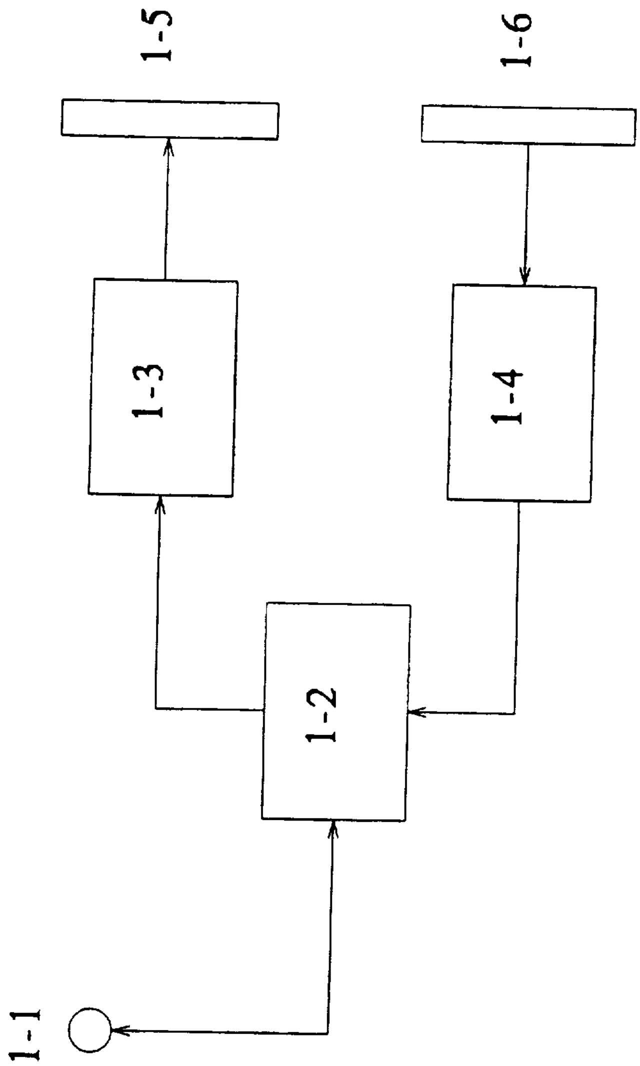


Fig. 1

Login unit base station

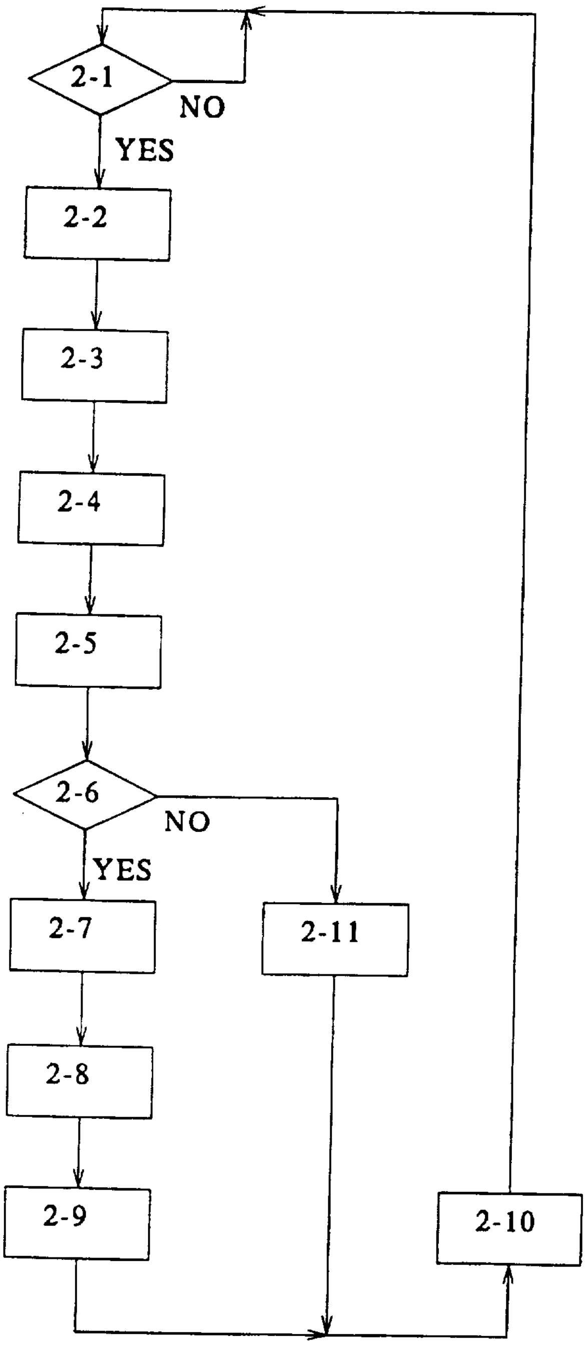


Fig. 2

Operation of login section at base station

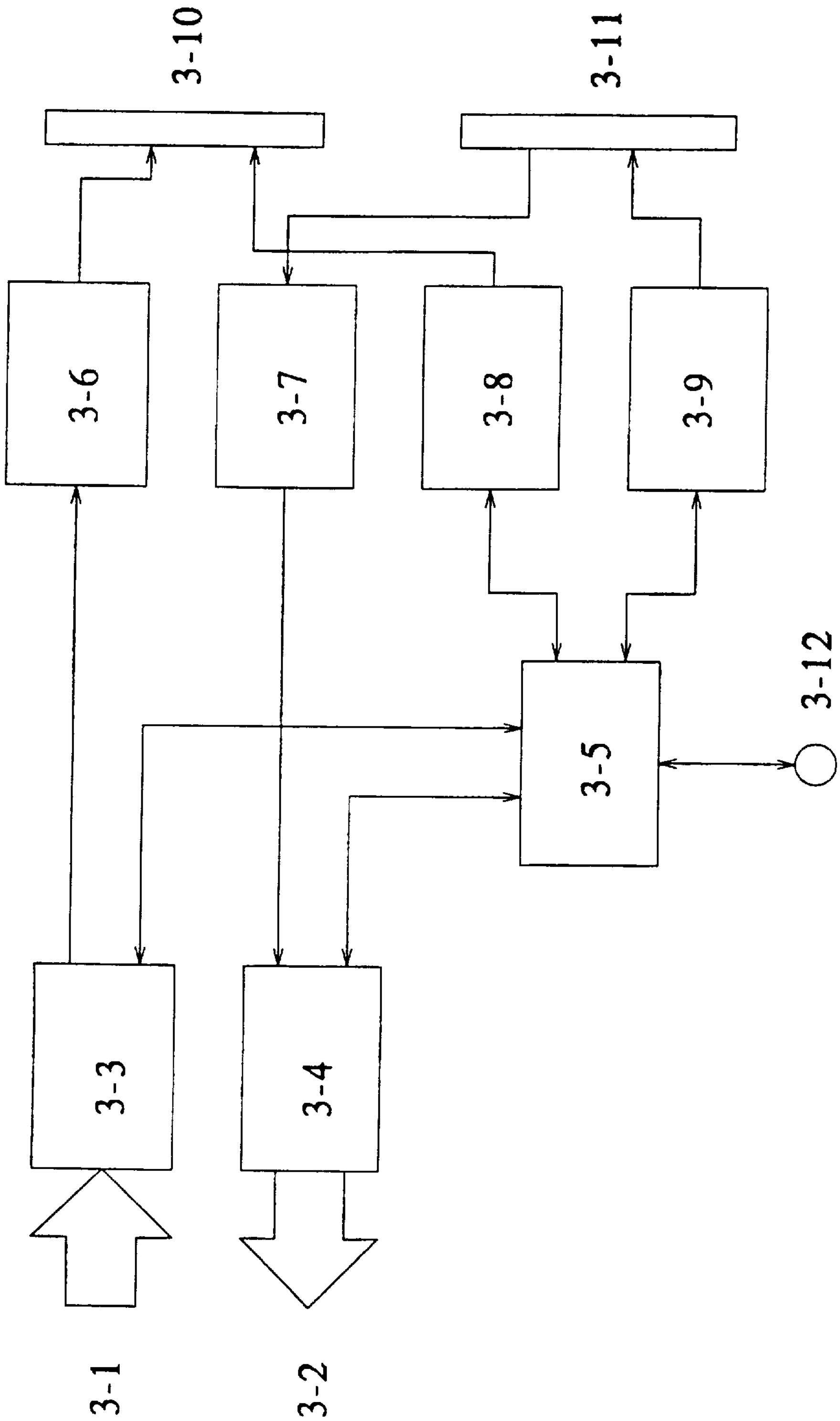


Fig.3

Operation unit base station

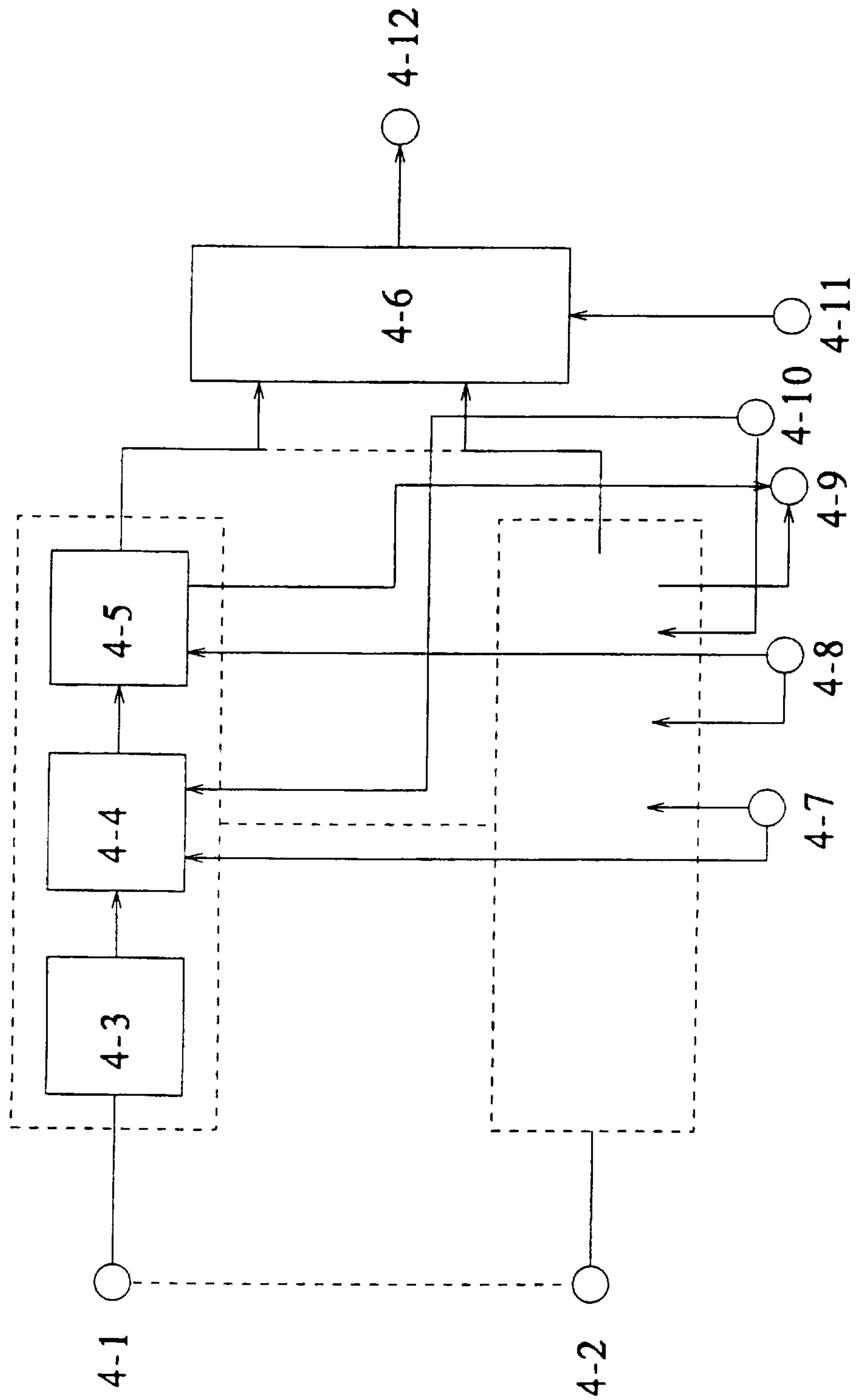


Fig. 4

Input data multiplexer base station

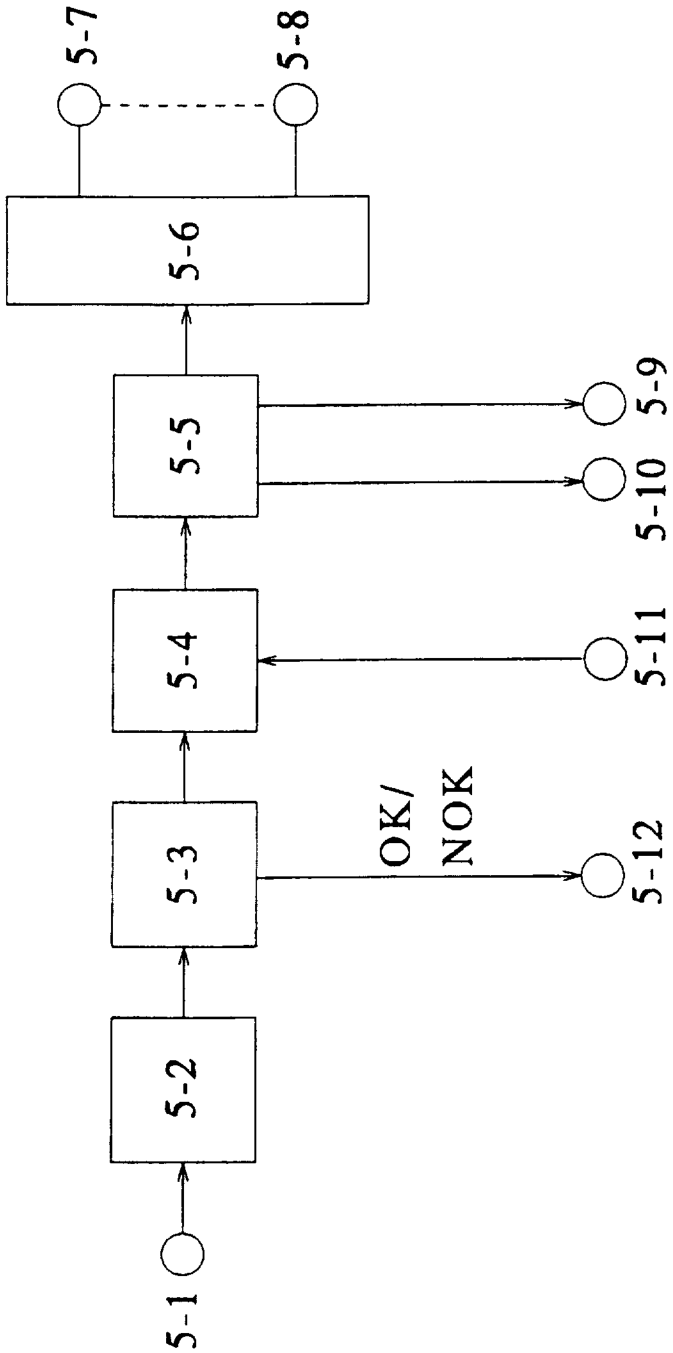


Fig. 5

Output data multiplexer base station

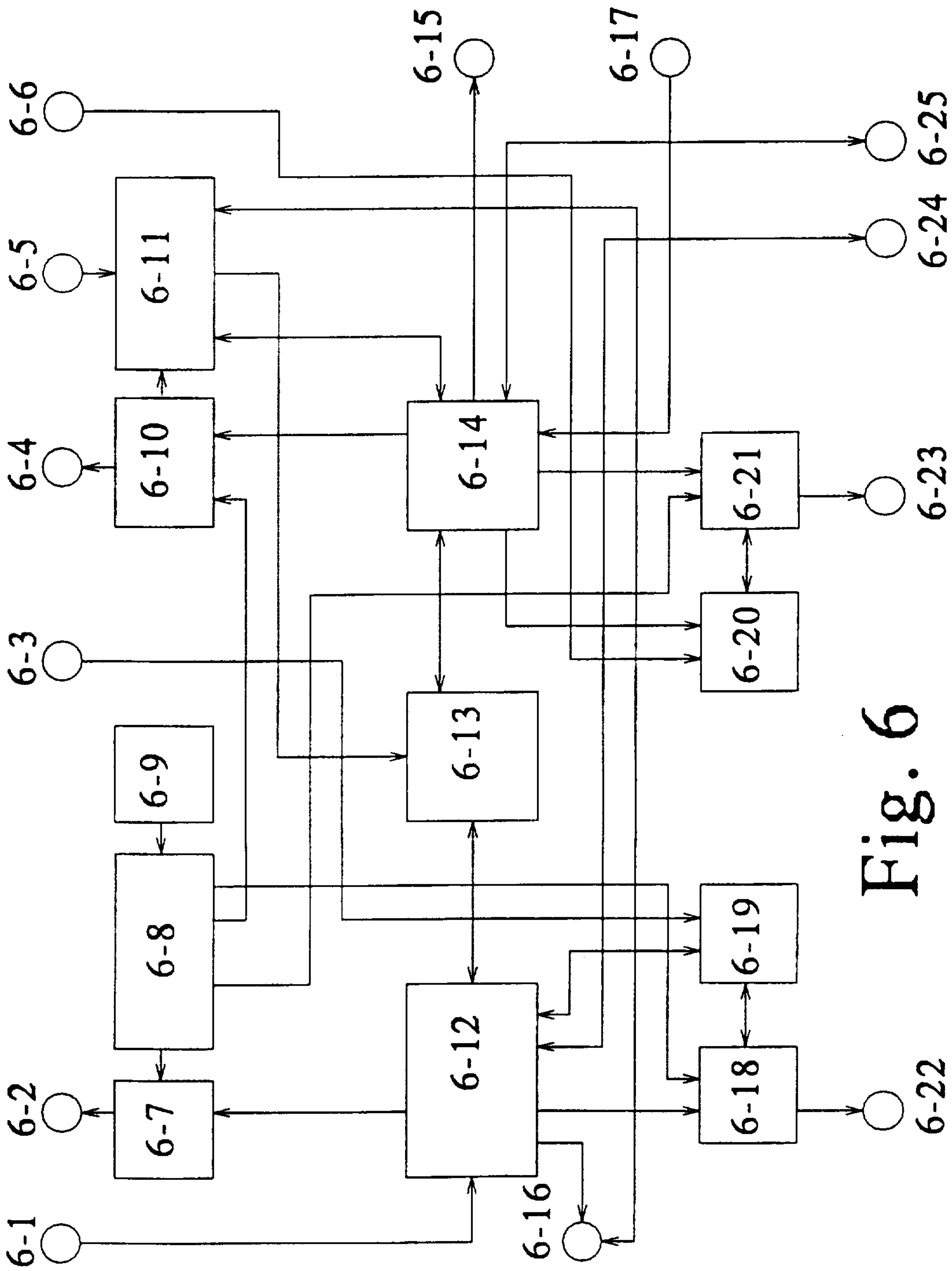


Fig. 6

System control base station

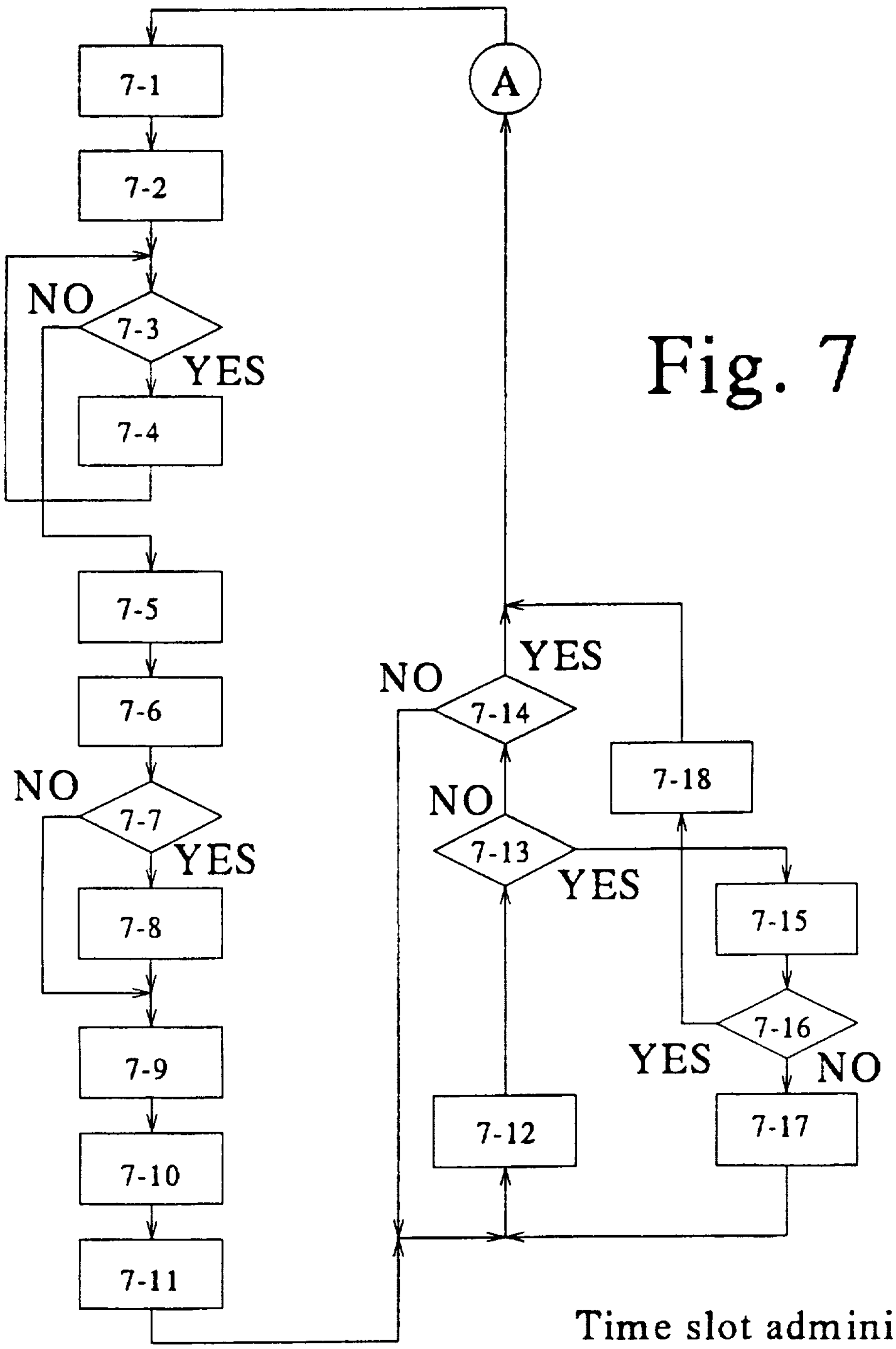


Fig. 7

Time slot administration
trnsmission operation
(base station)

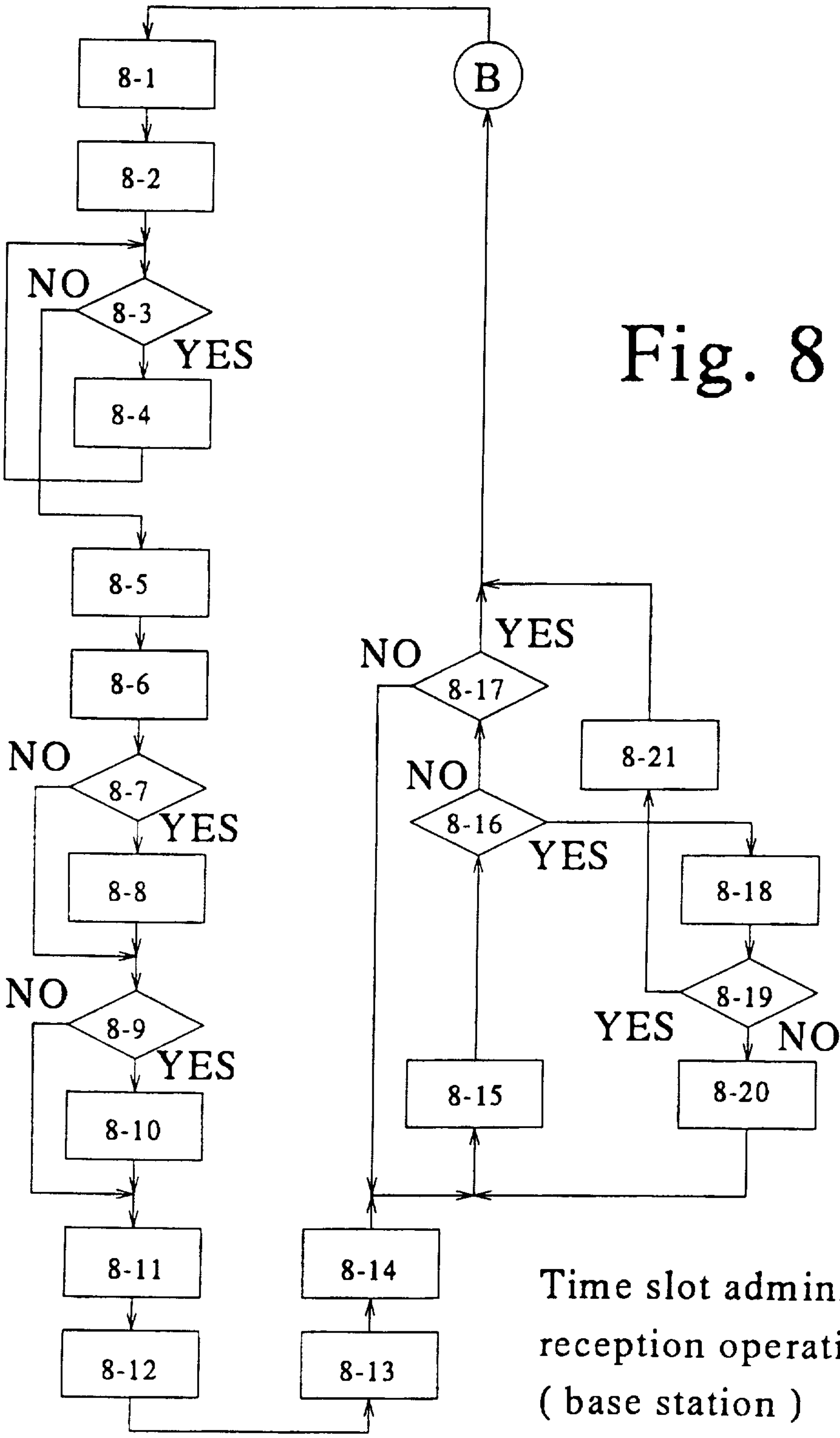


Fig. 8

Time slot administration
reception operation
(base station)

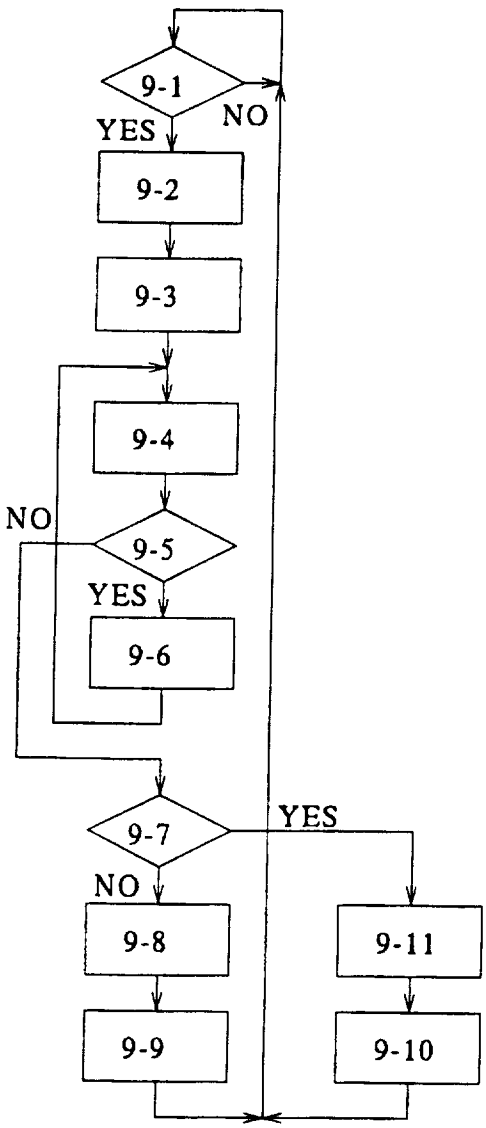
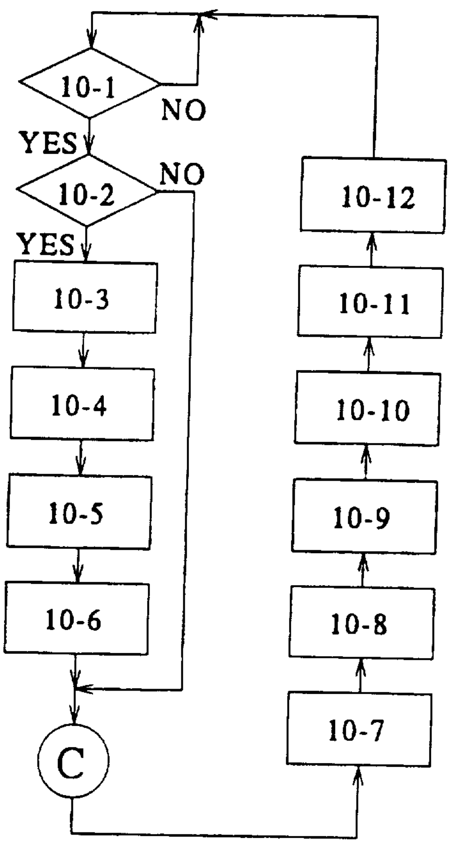


Fig. 9

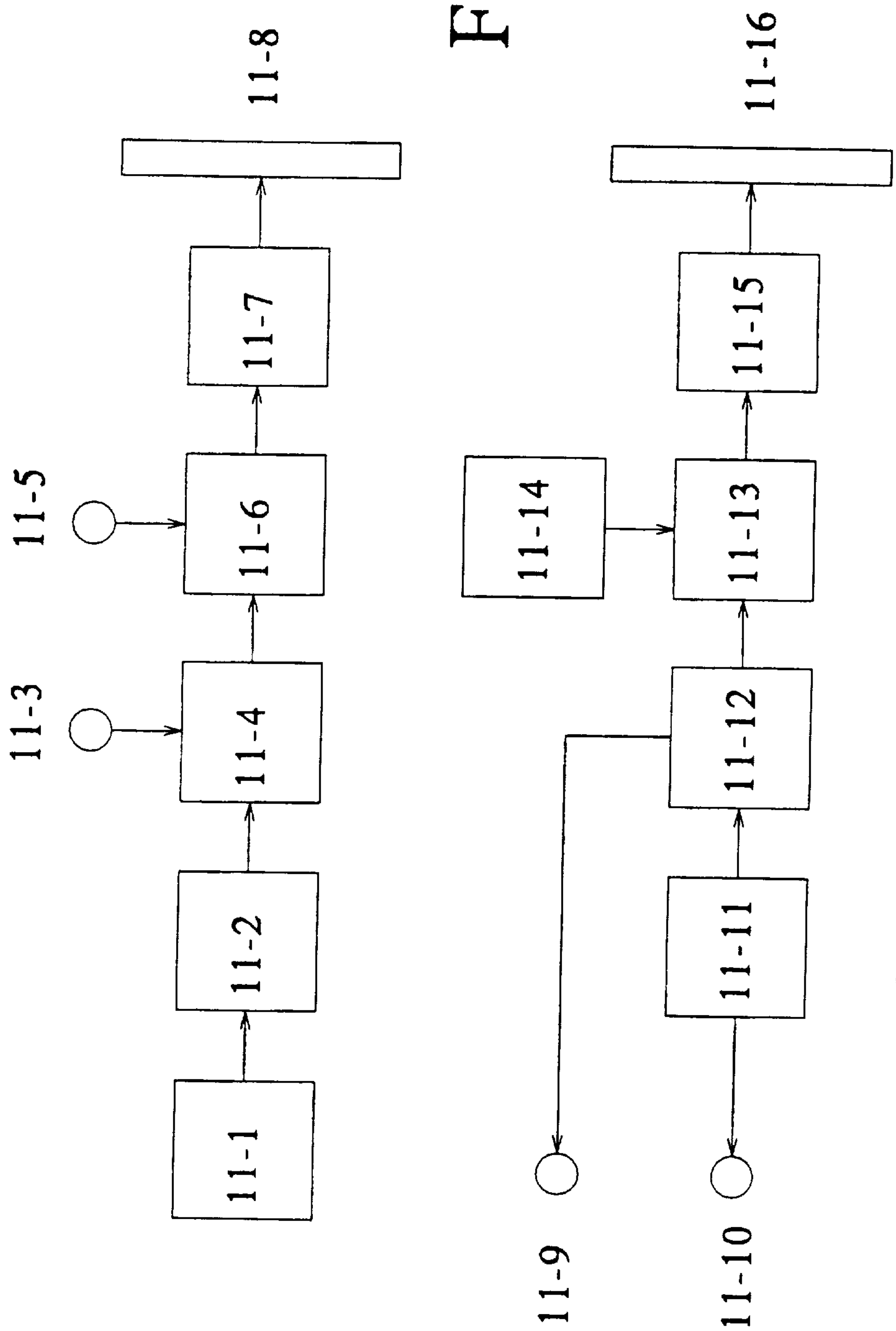
Transmit / receive collision avoidance at subscriber station operation (base station)



Operation of dither control (base station)

Fig. 10

Fig. 11



RF - System base station

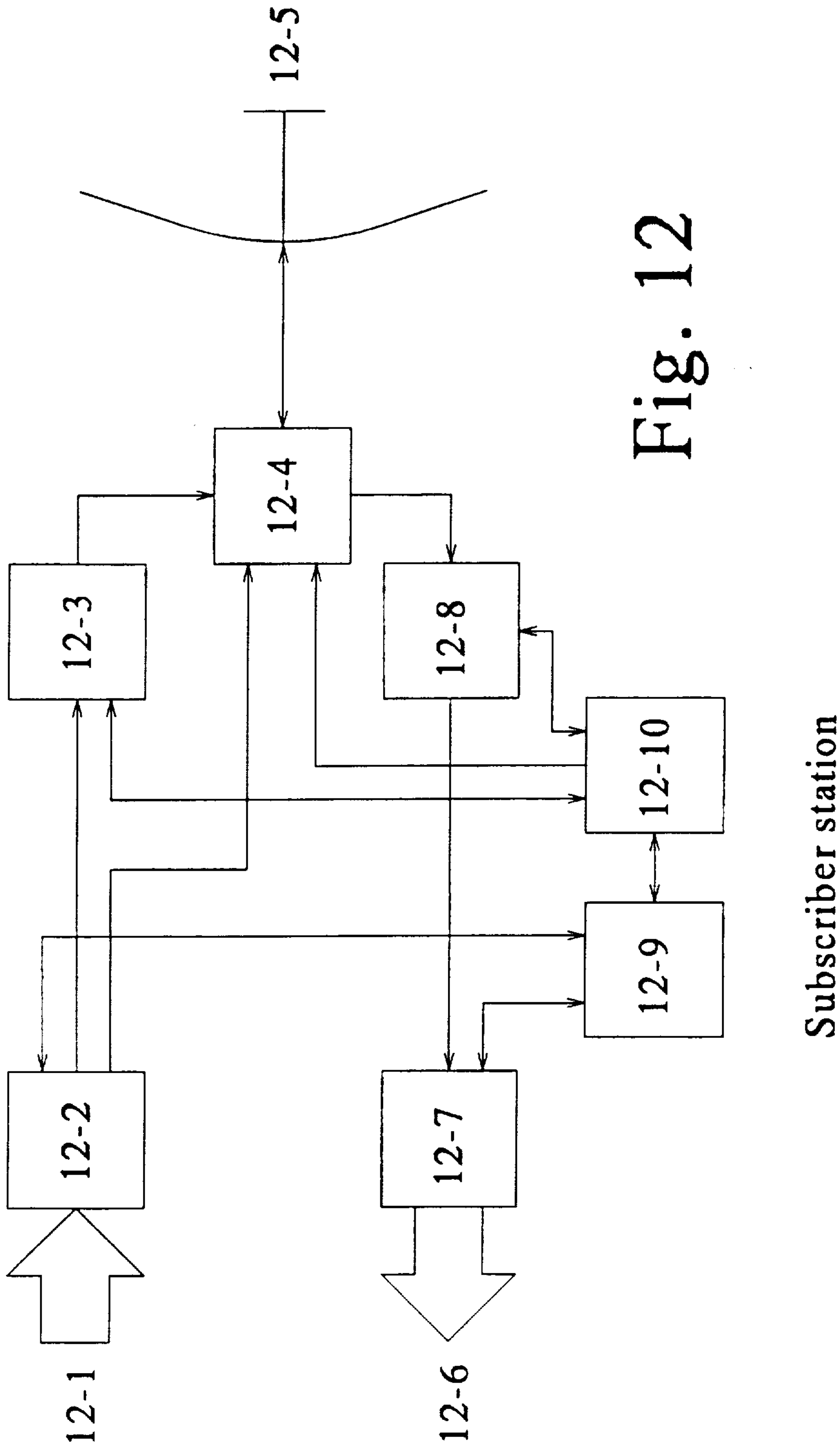
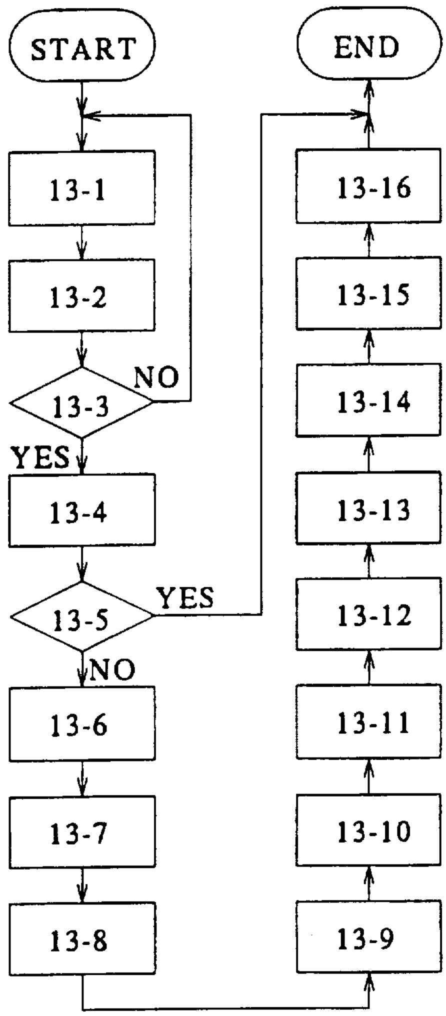


Fig. 12



Operation of login section at subscriber station

Fig. 13

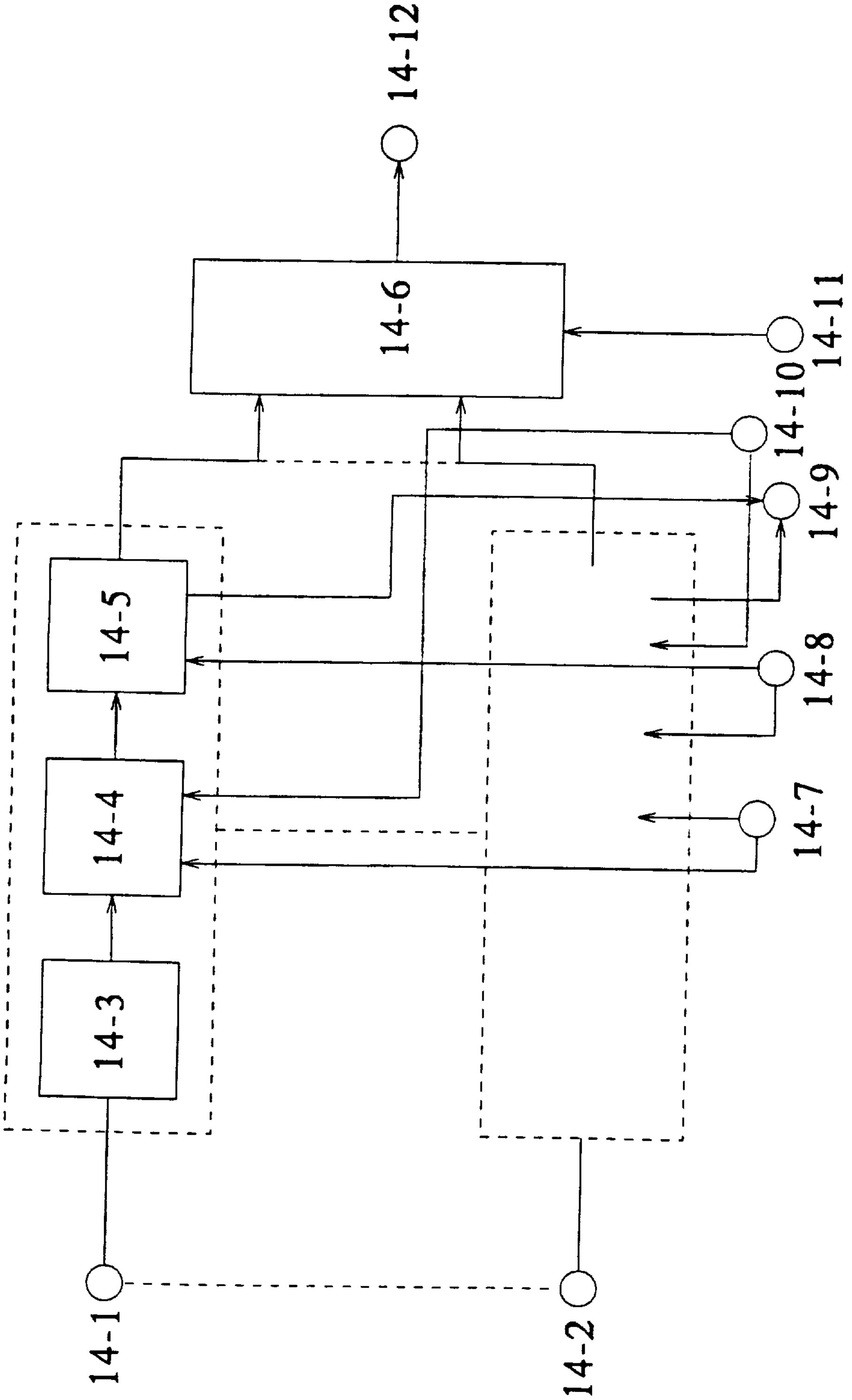
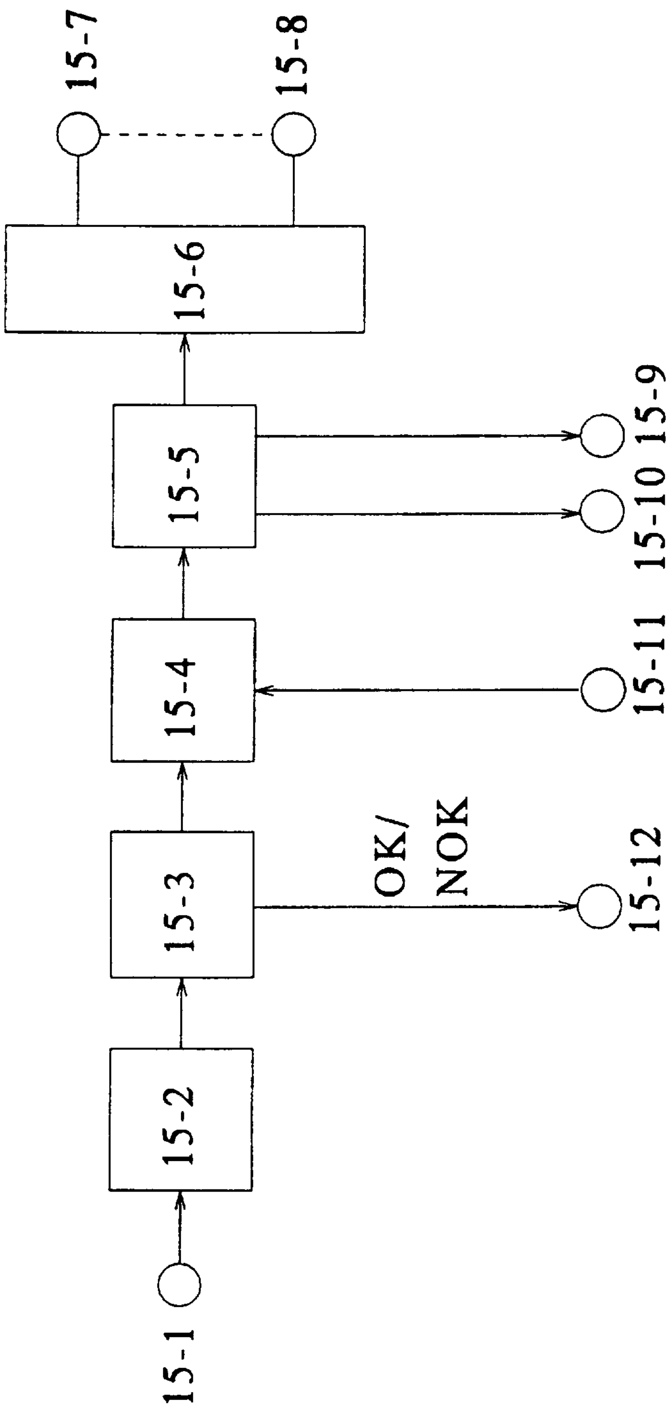


Fig. 14

Input data multiplexer subscriber station



Output data demultiplexer subscriber station

Fig. 15

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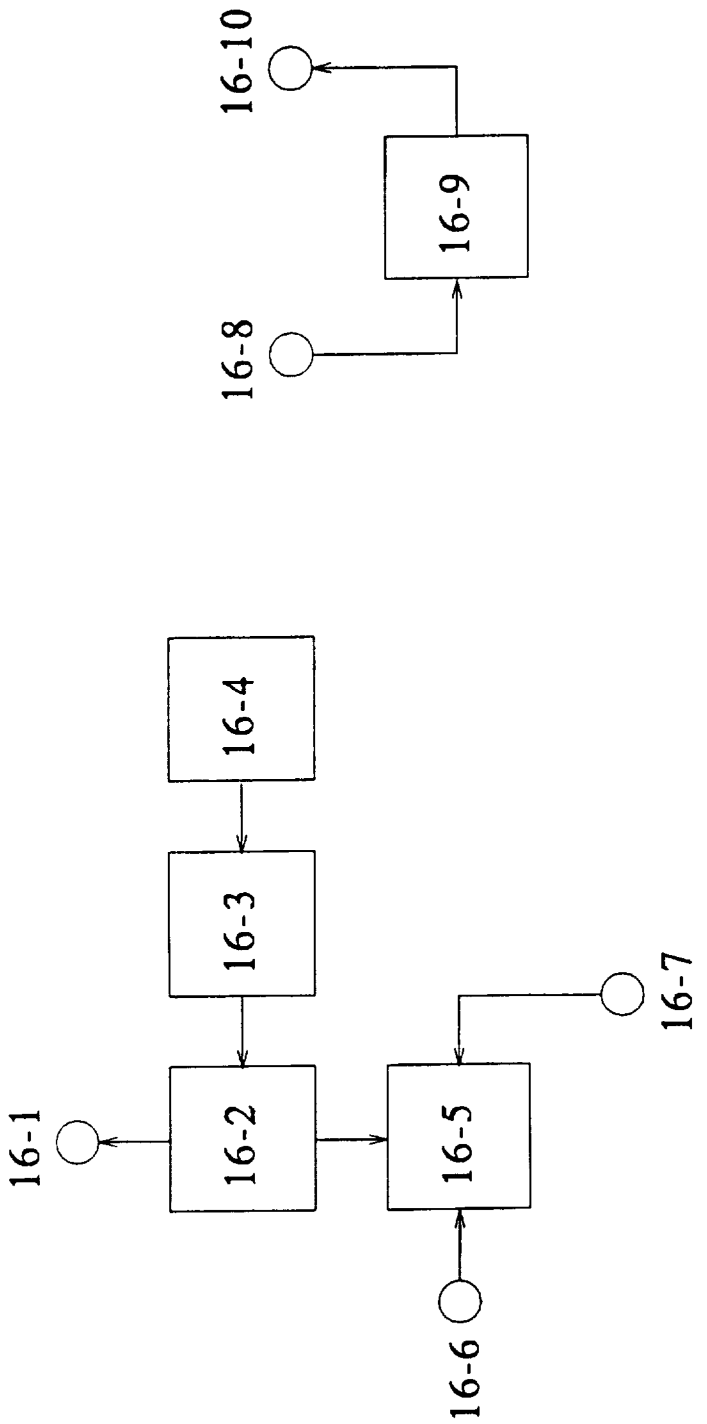


Fig. 16

System control section of subscriber station

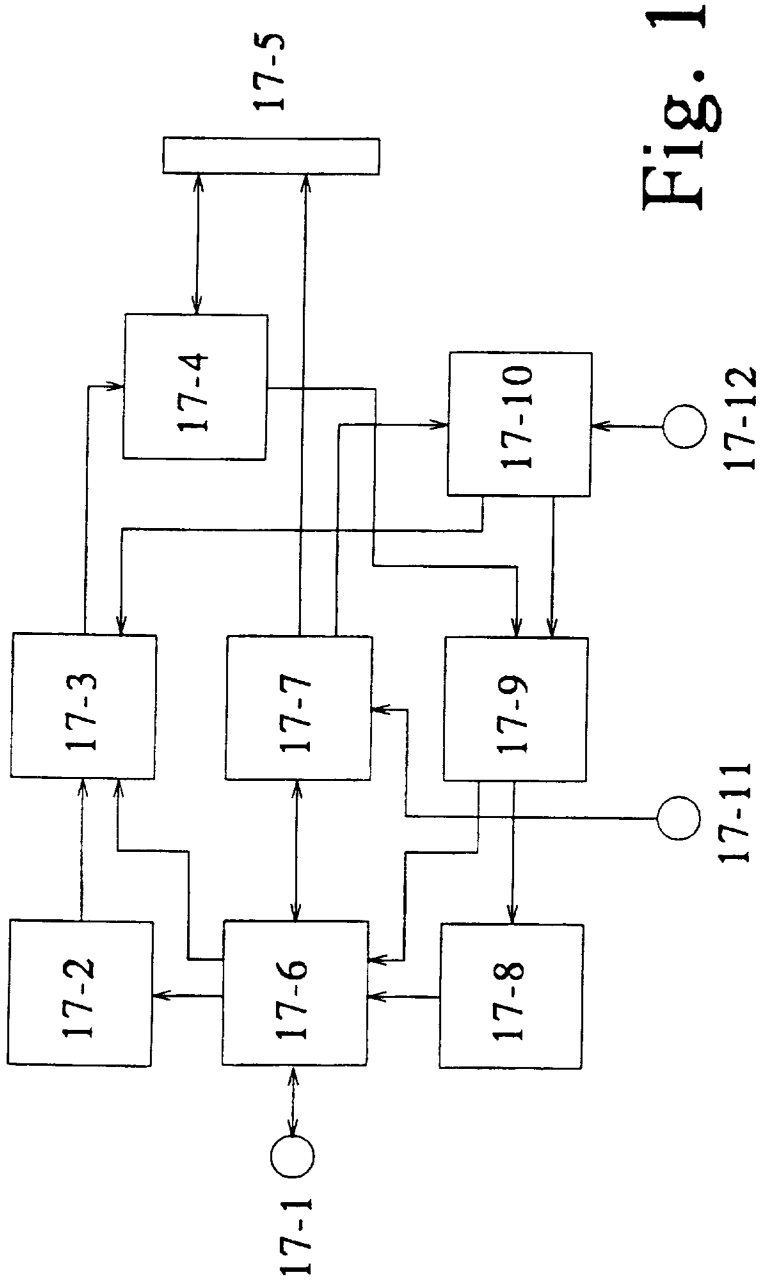


Fig. 17

Login control base station

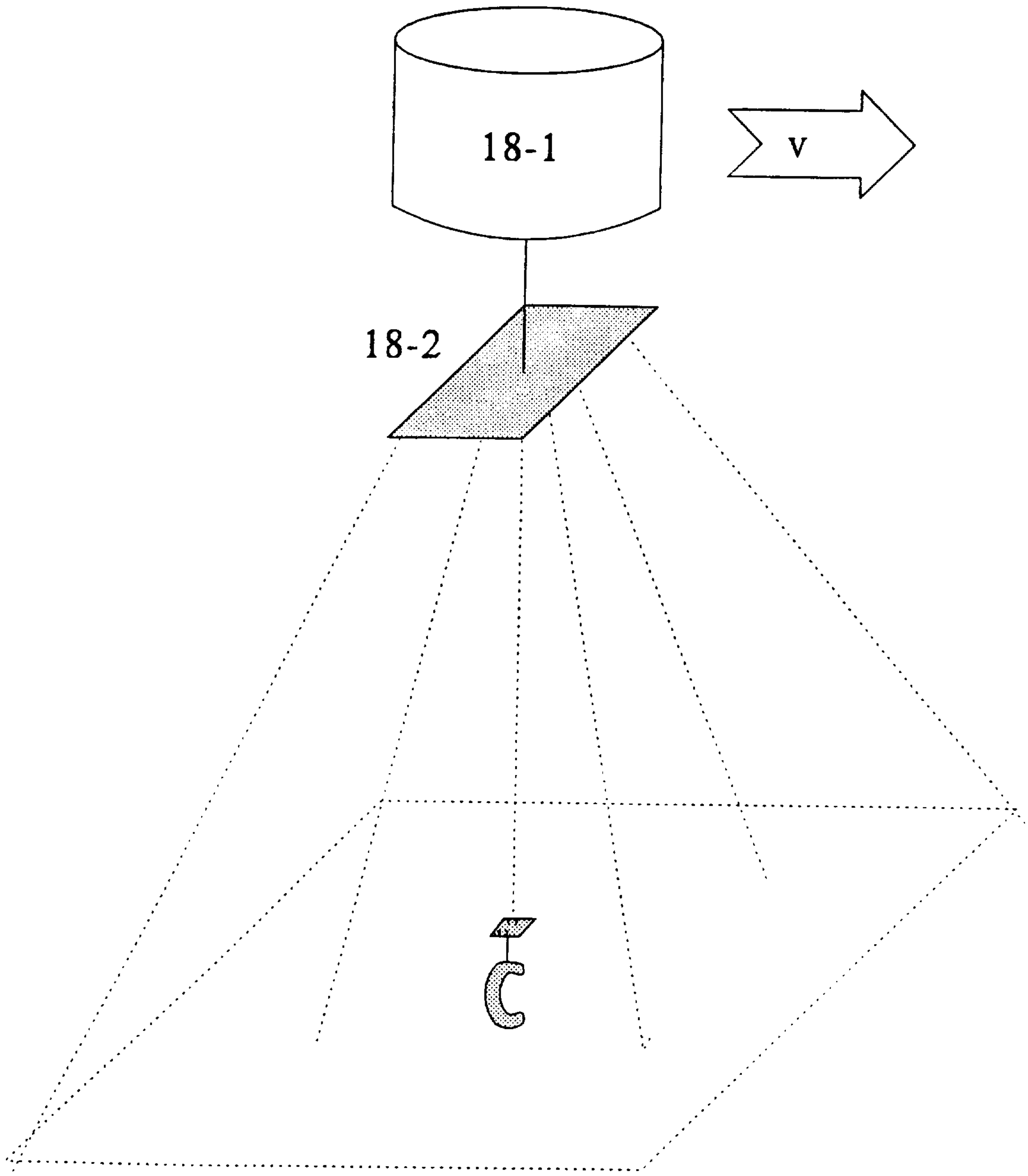
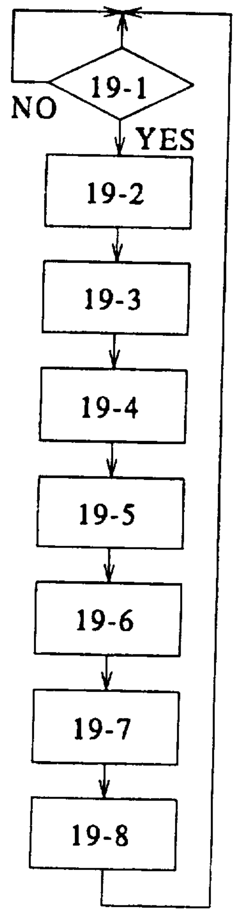
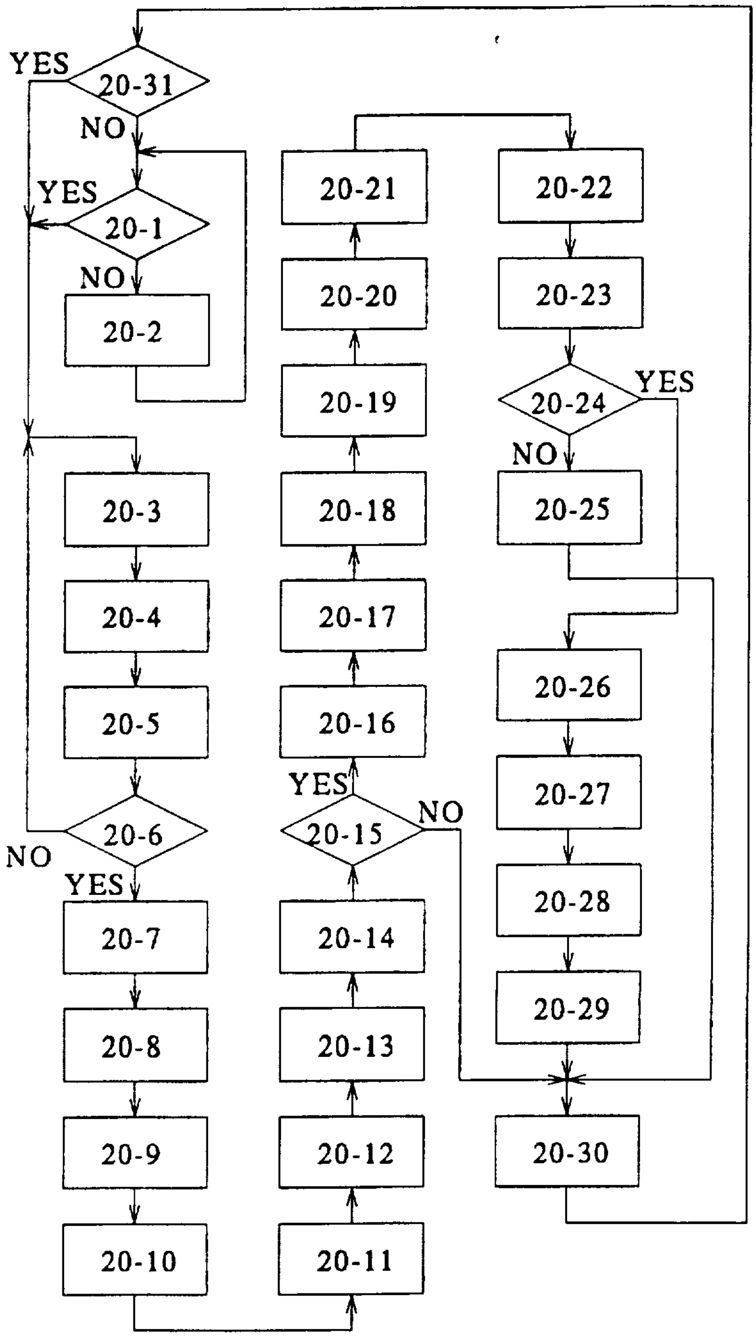


Fig. 18



Operation of doppler compensation of login unit of base station

Fig. 19



Login unit operation base station

Fig. 20

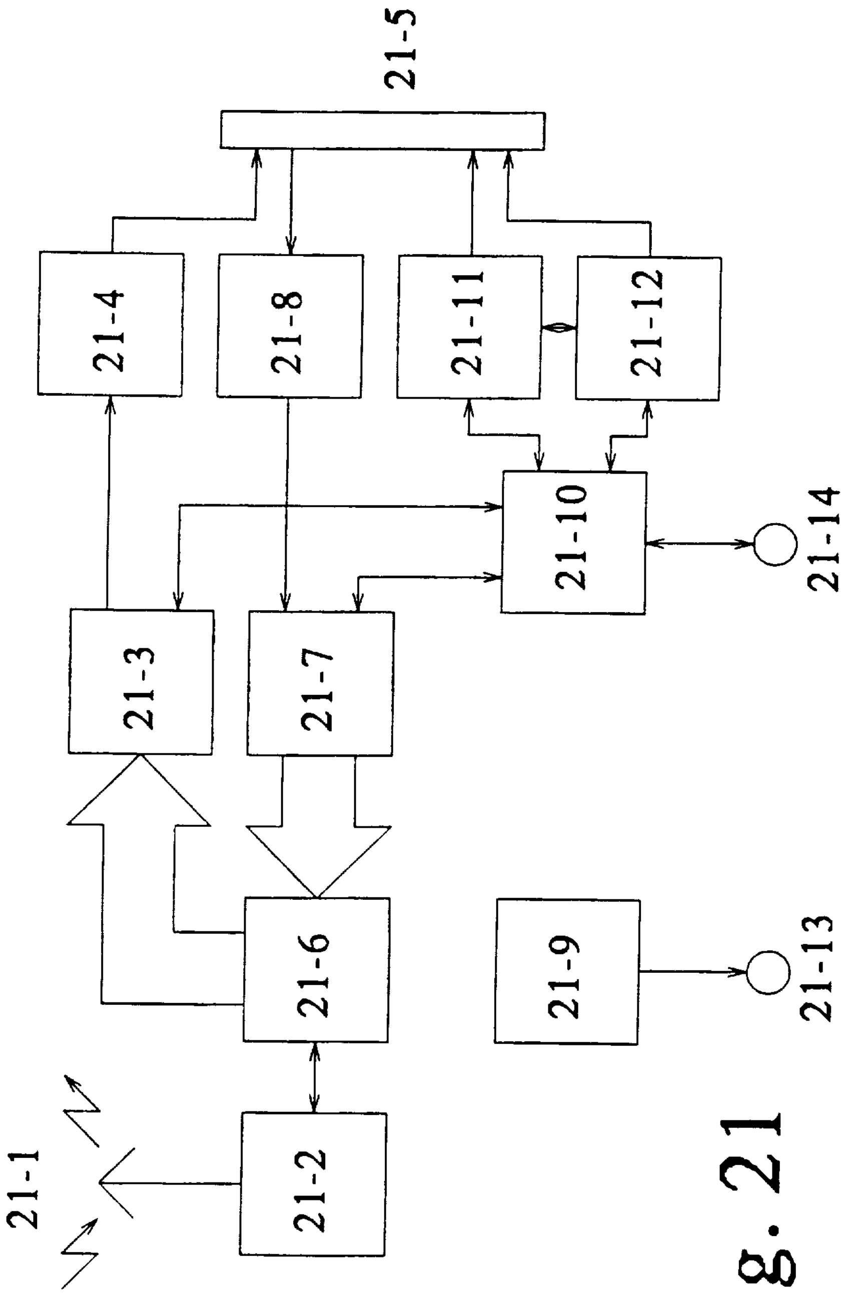


Fig. 21

Operation unit base station

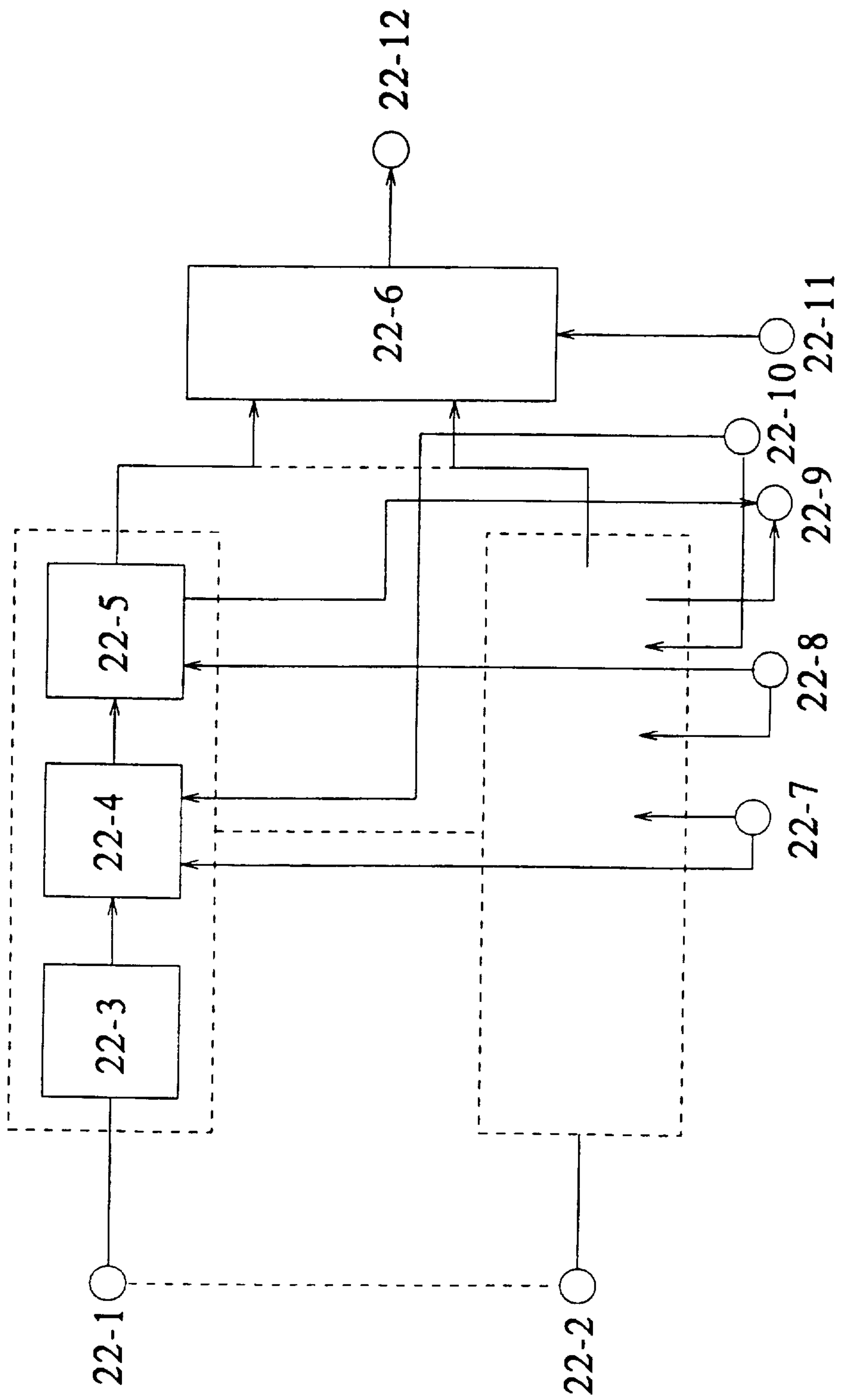


Fig. 22

Input data multiplexer base station

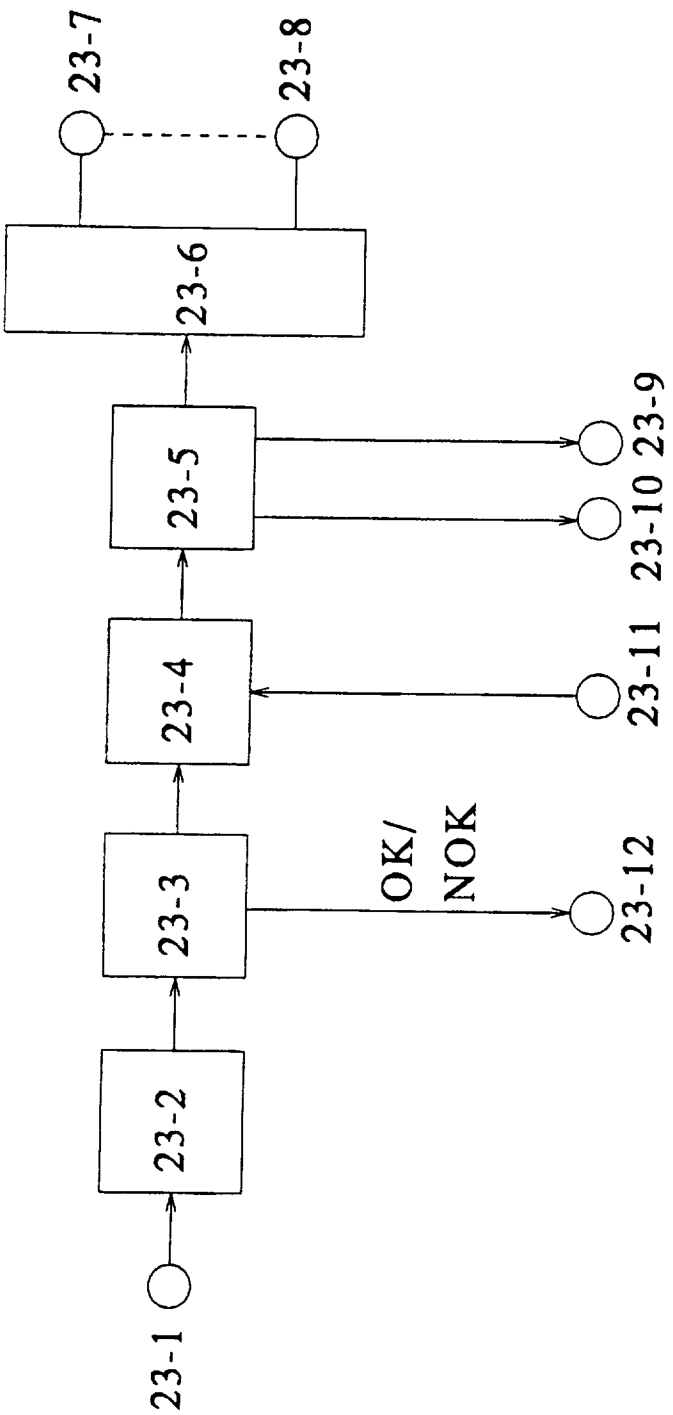
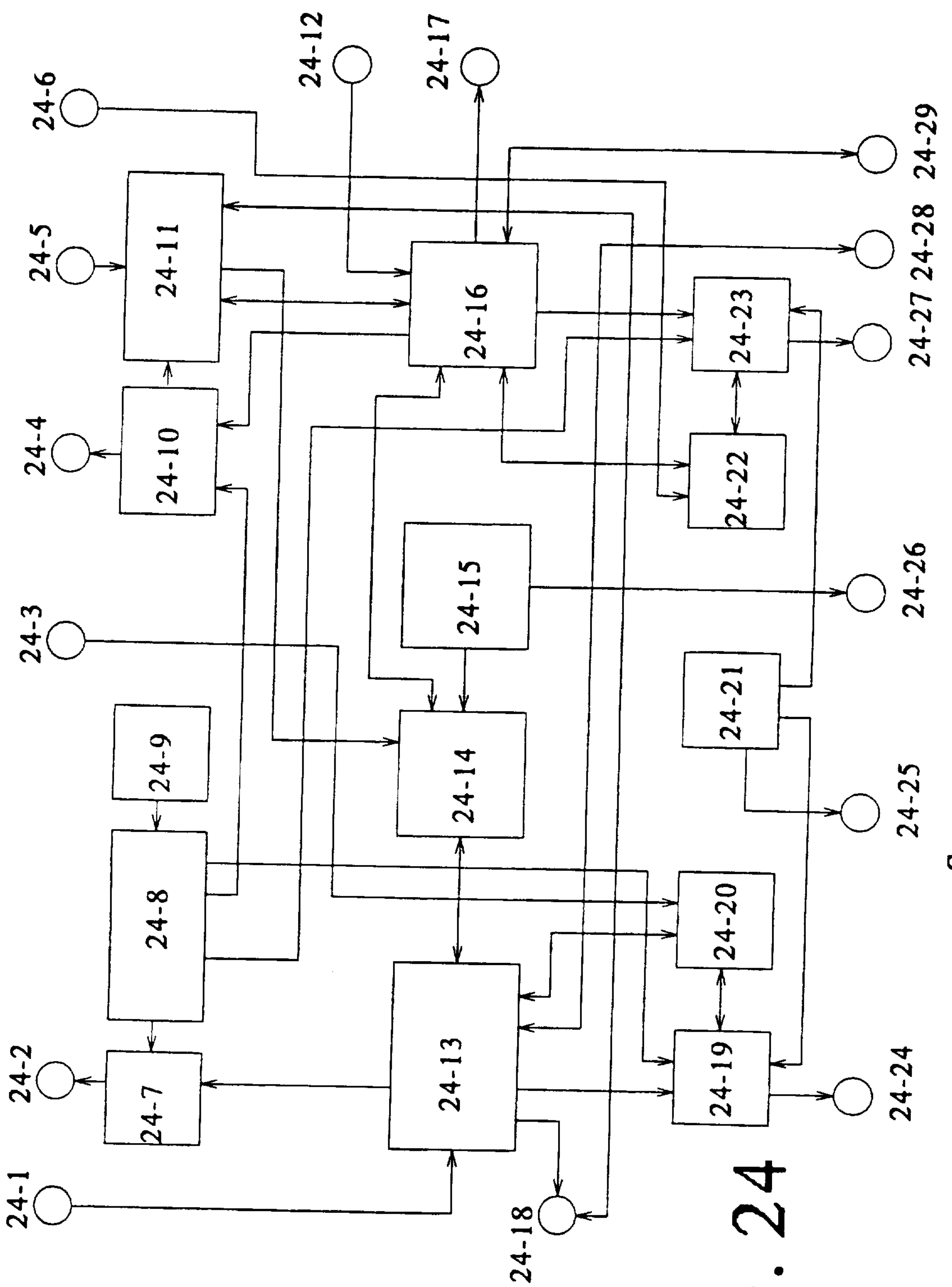


Fig. 23

Output data demultiplexer base station



System control base station

Fig. 24

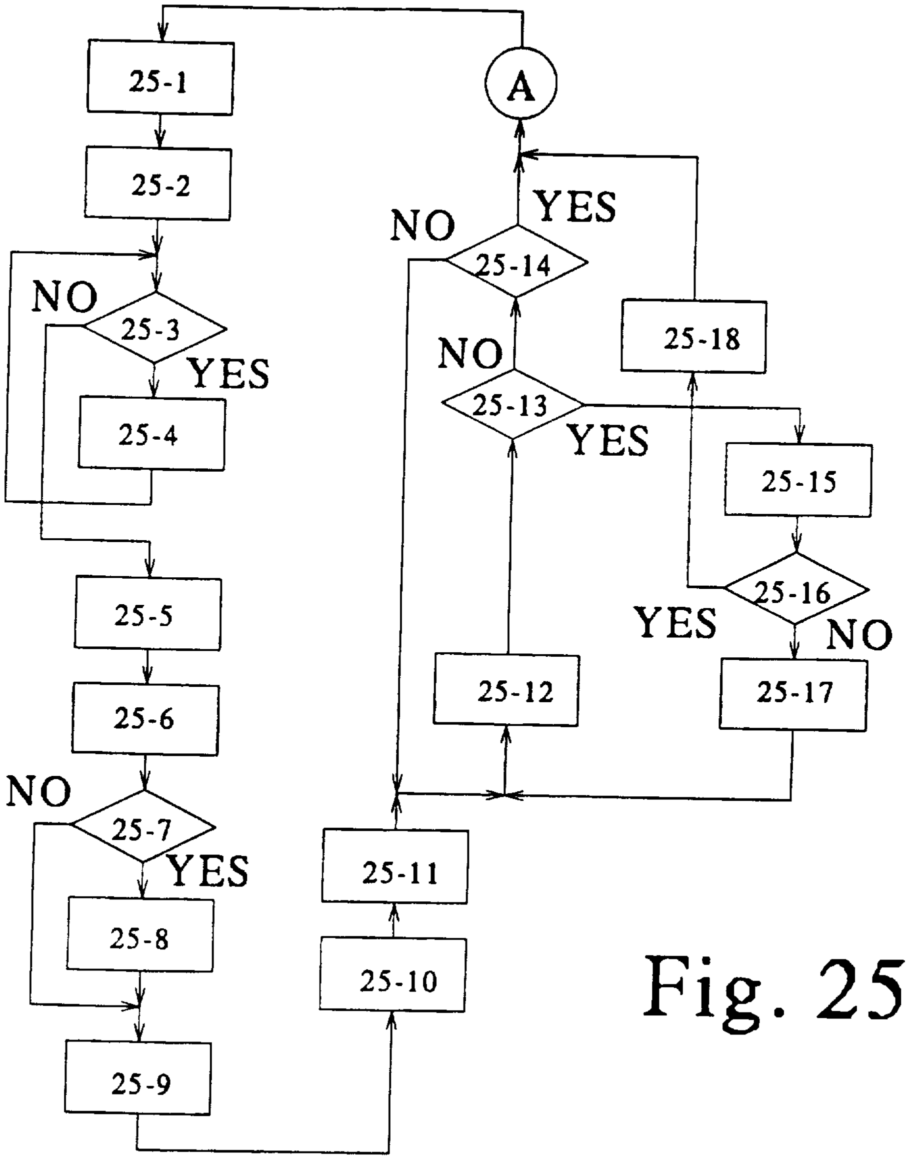


Fig. 25

Time slot administration transmission operation

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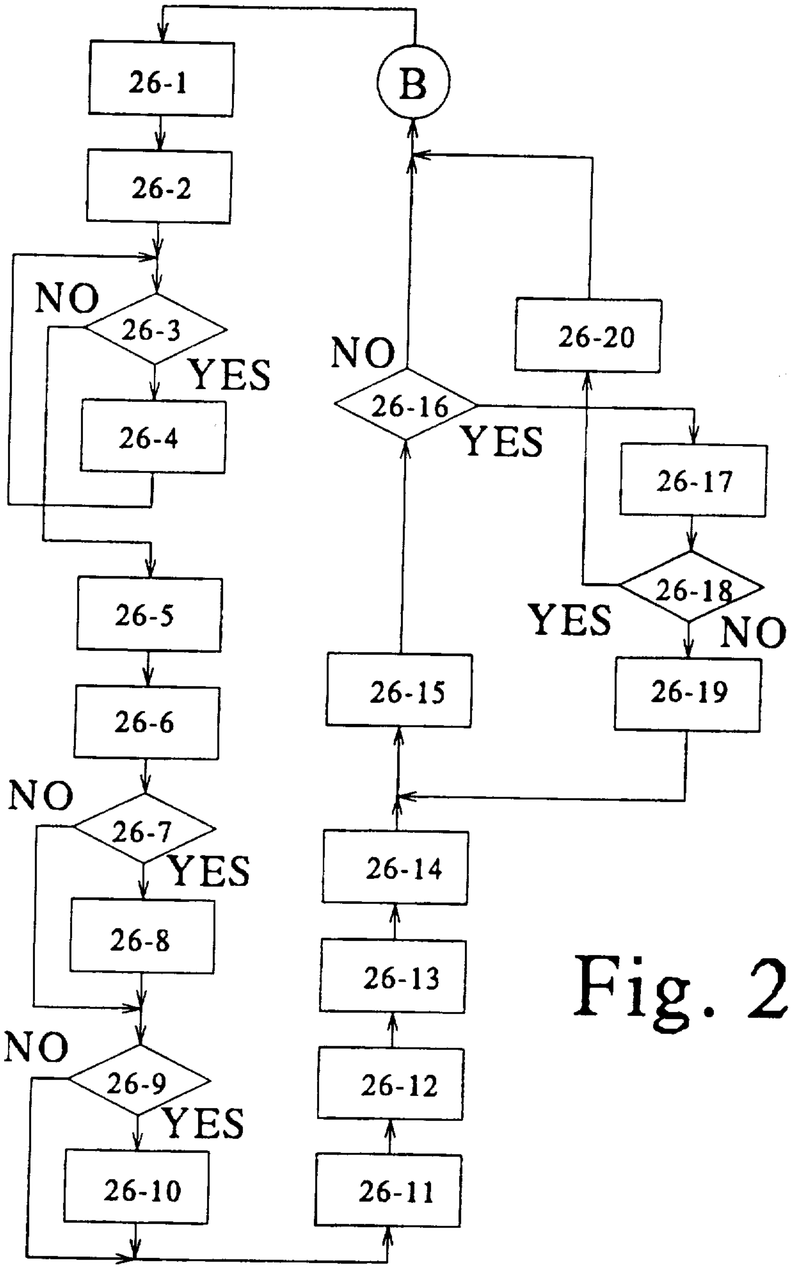


Fig. 26

Time slot administration reception operation

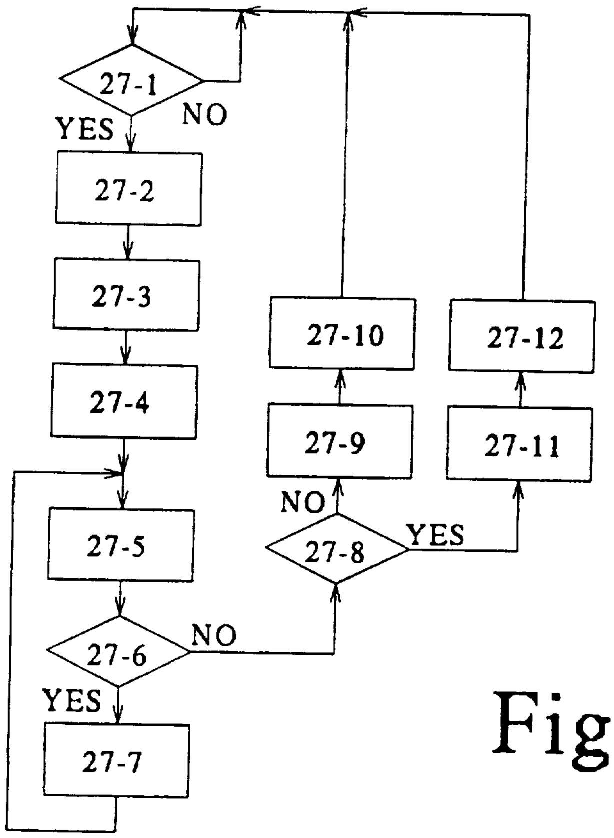
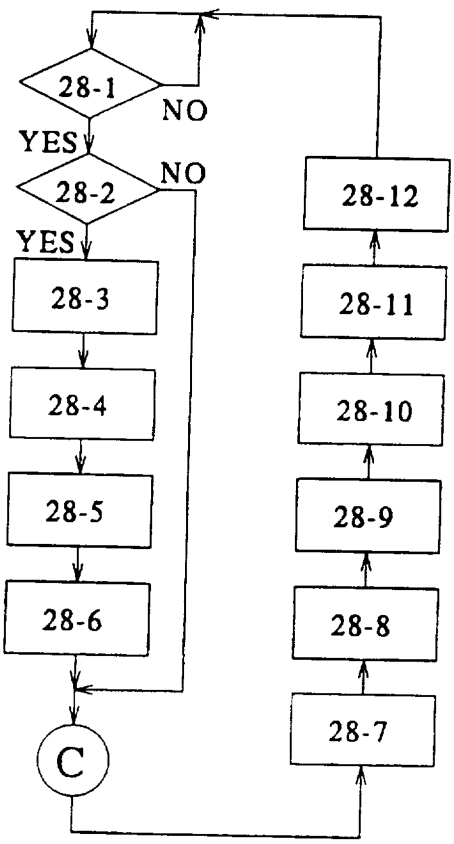


Fig. 27

Transmit / receive collision avoidance at subscriber station operation (base station)



Operation of dither control (base station)

Fig. 28

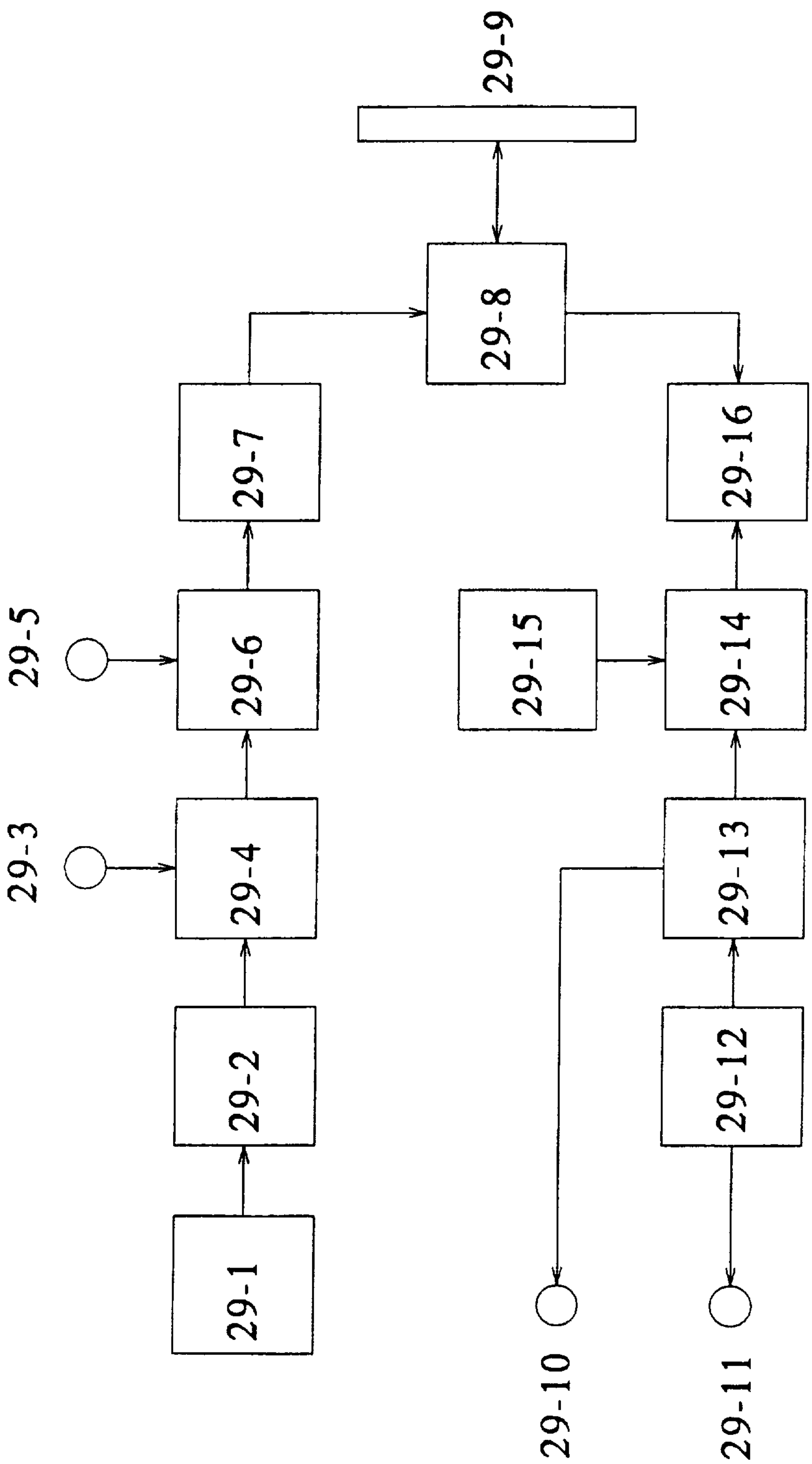


Fig. 29

RF - System base station

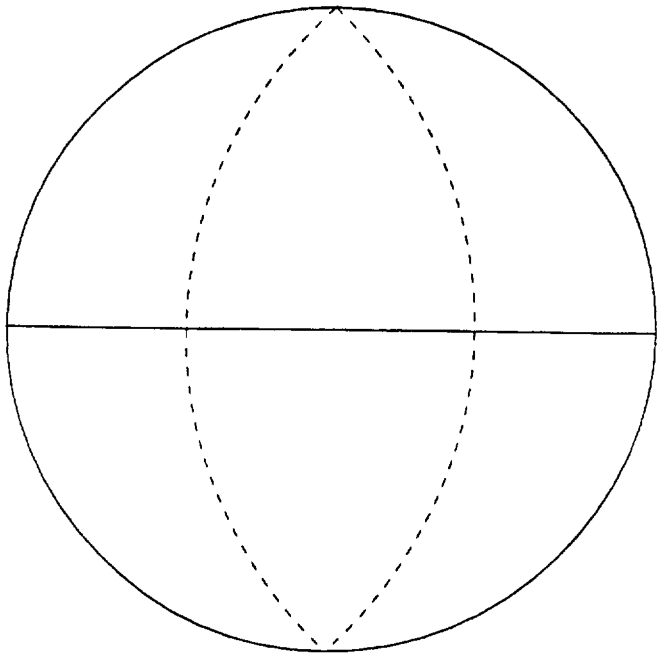


Fig. 30

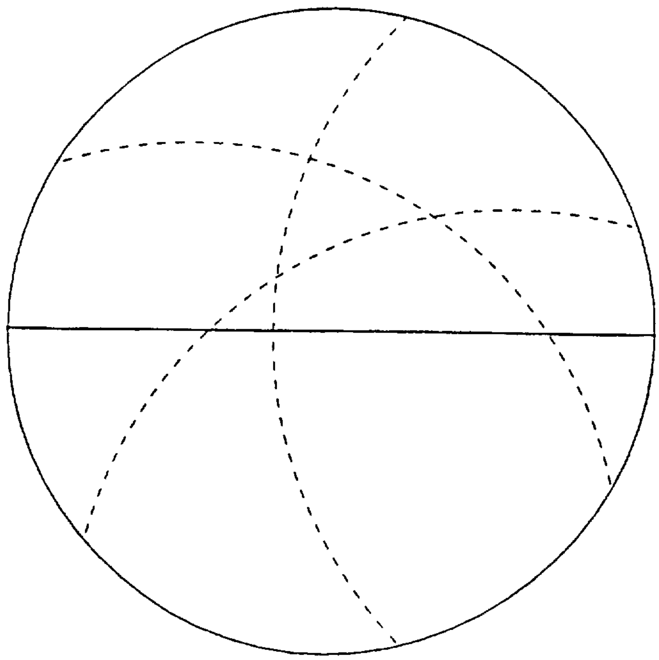
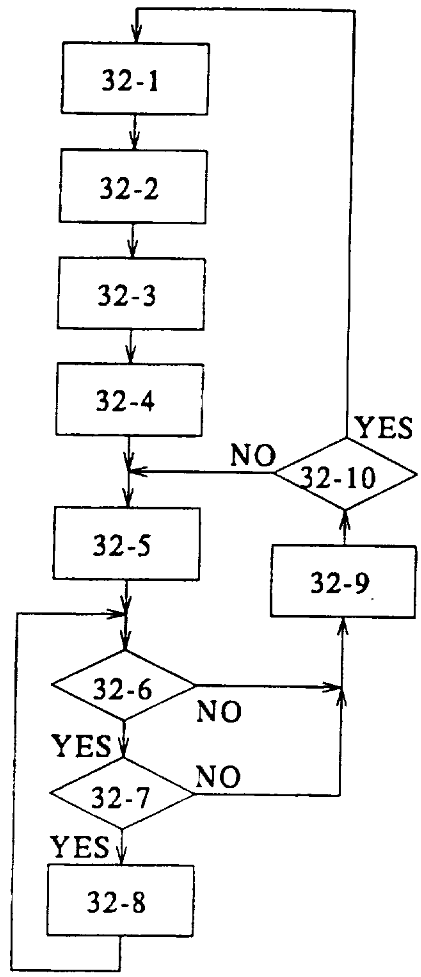
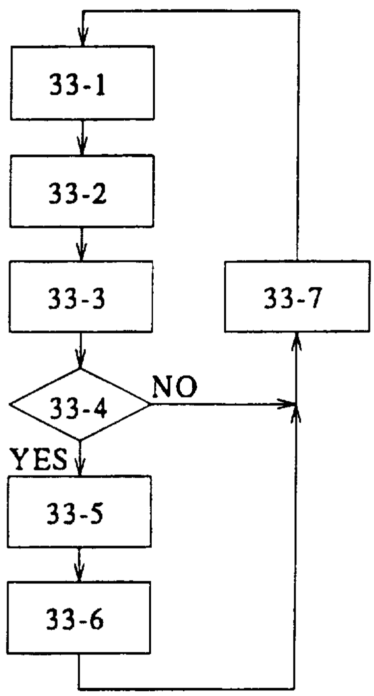


Fig. 31



Turning satellites into standby mode

Fig. 32



Reactivating satellites from standby mode

Fig. 33

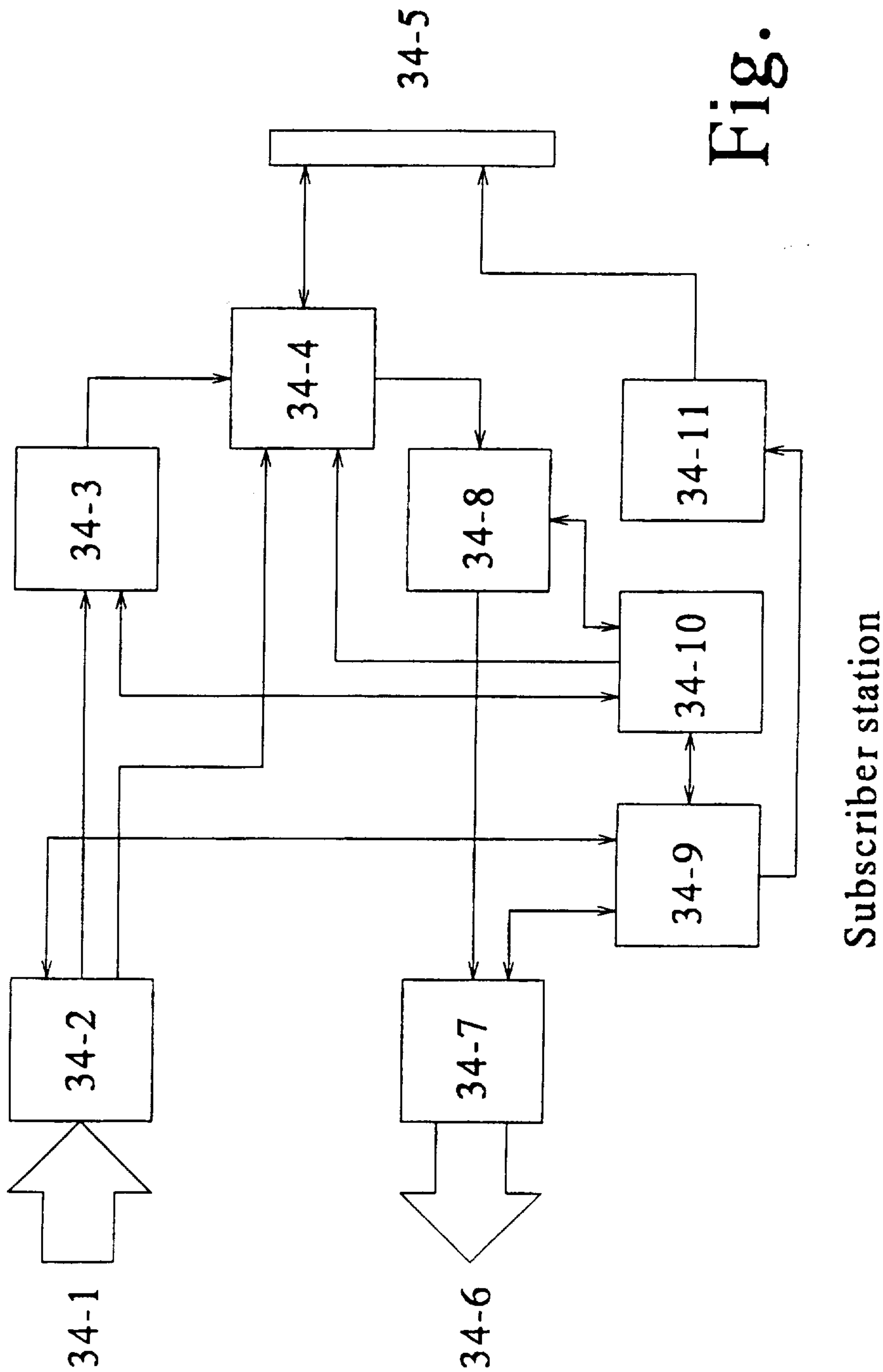
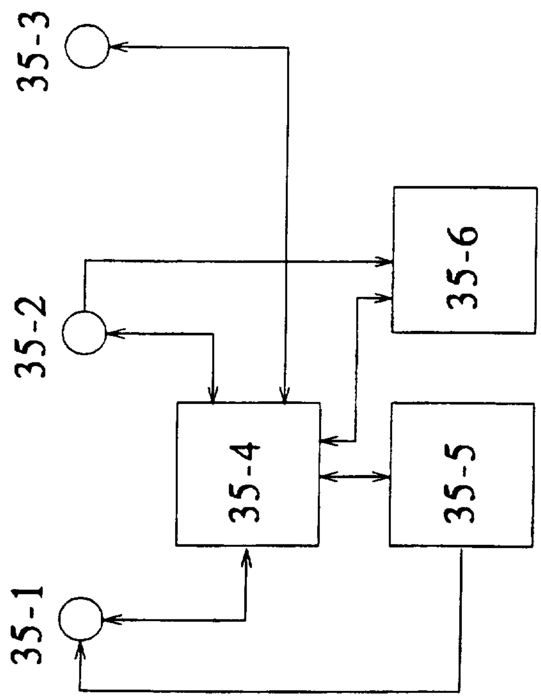

34-1
34-2
34-3
34-4
34-5
34-6
34-7
34-8
34-9
34-10
34-11
Subscriber station

Fig. 34

Fig. 35



Login control section of subscriber station

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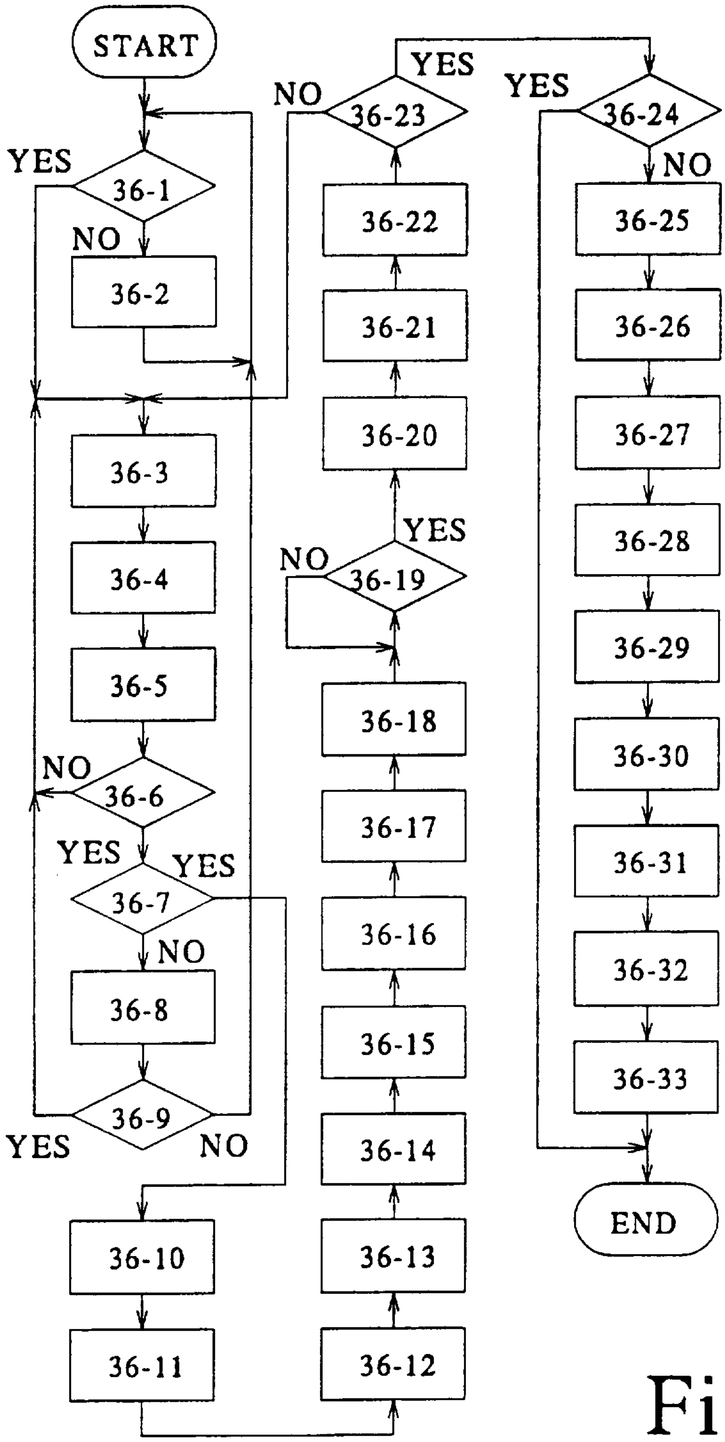

Fig. 36

Operation of login section at subscriber station

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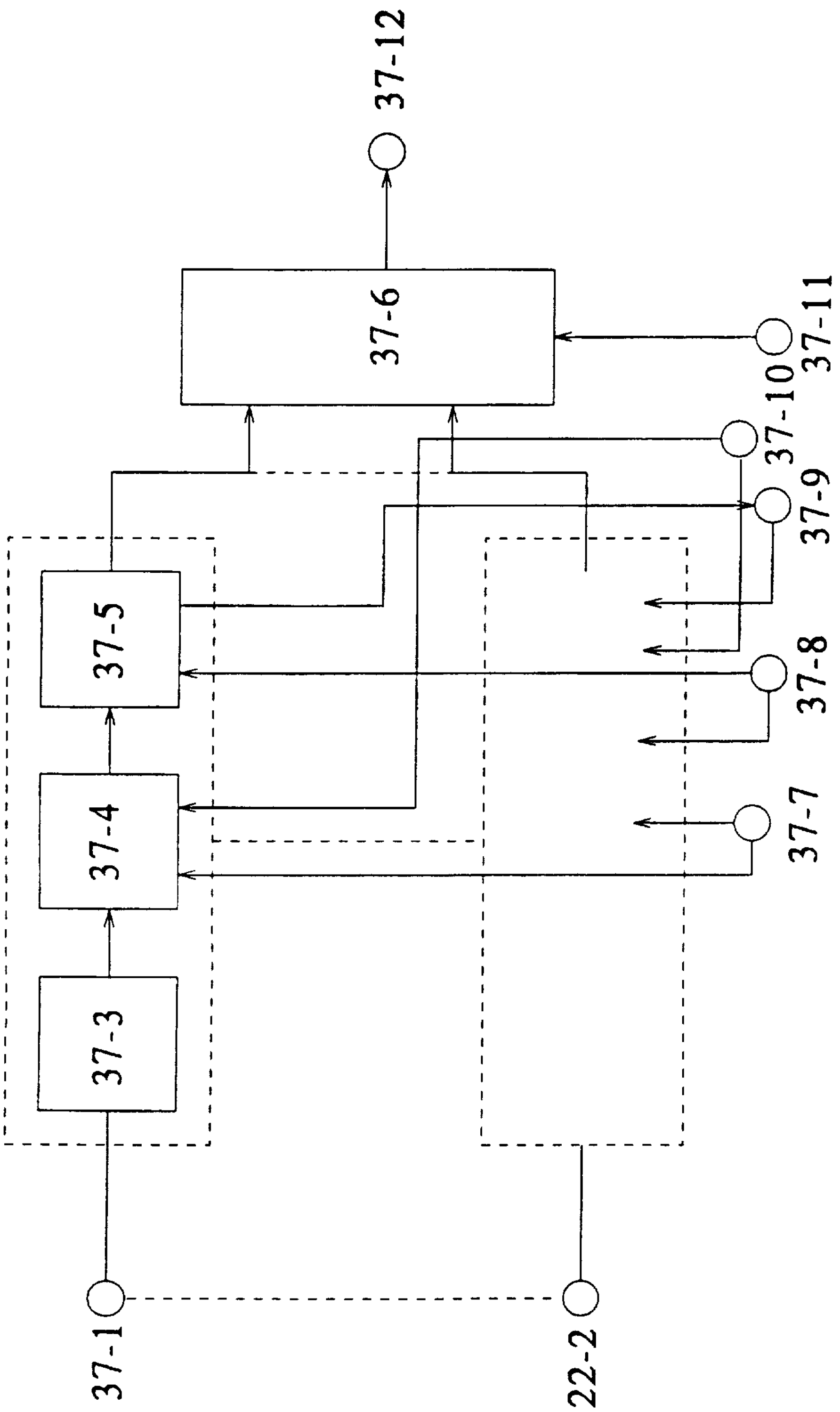


Fig. 37

Input data multiplexer subscriber station

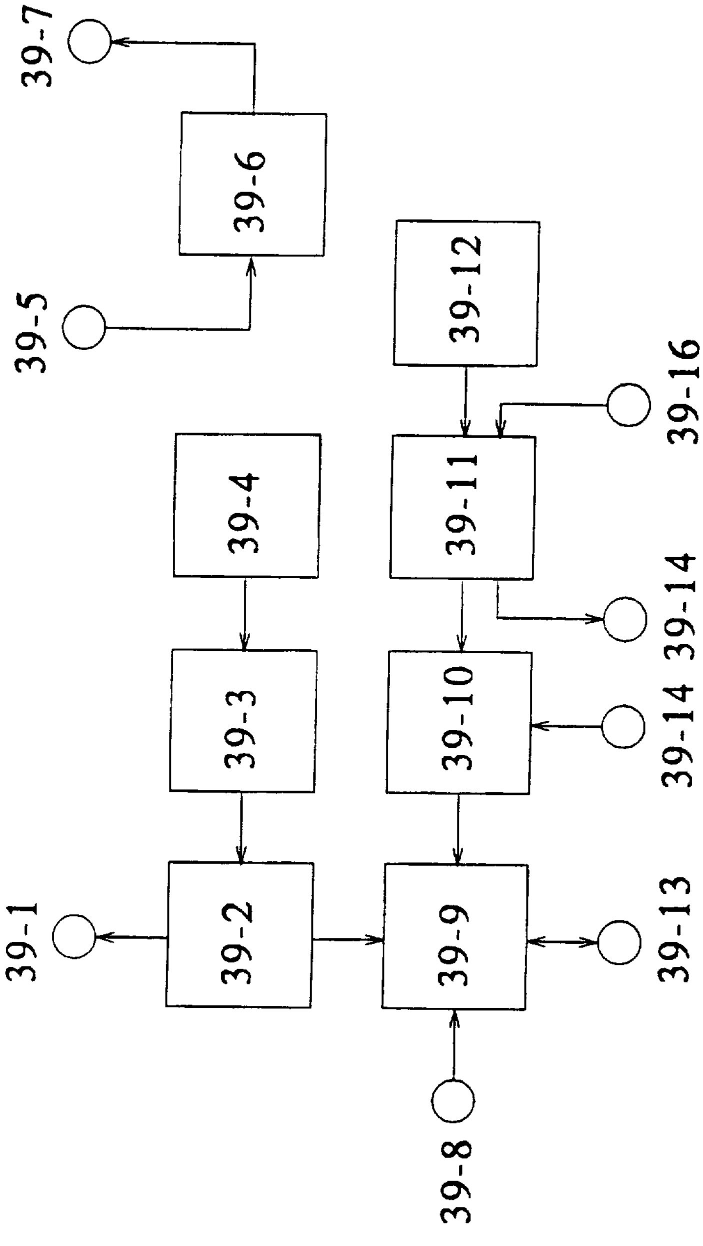
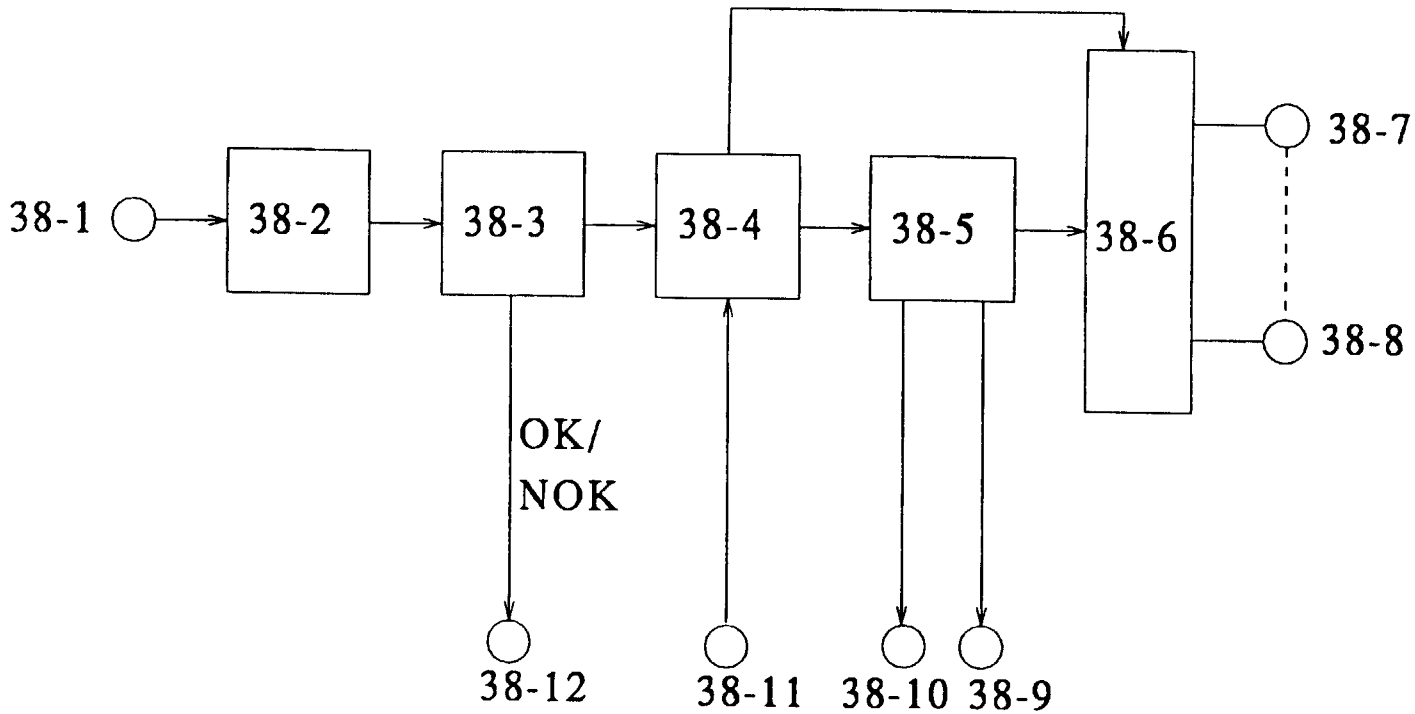


Fig. 39

System control section of subscriber station



Output data demultiplexer of subscriber station

Fig. 38

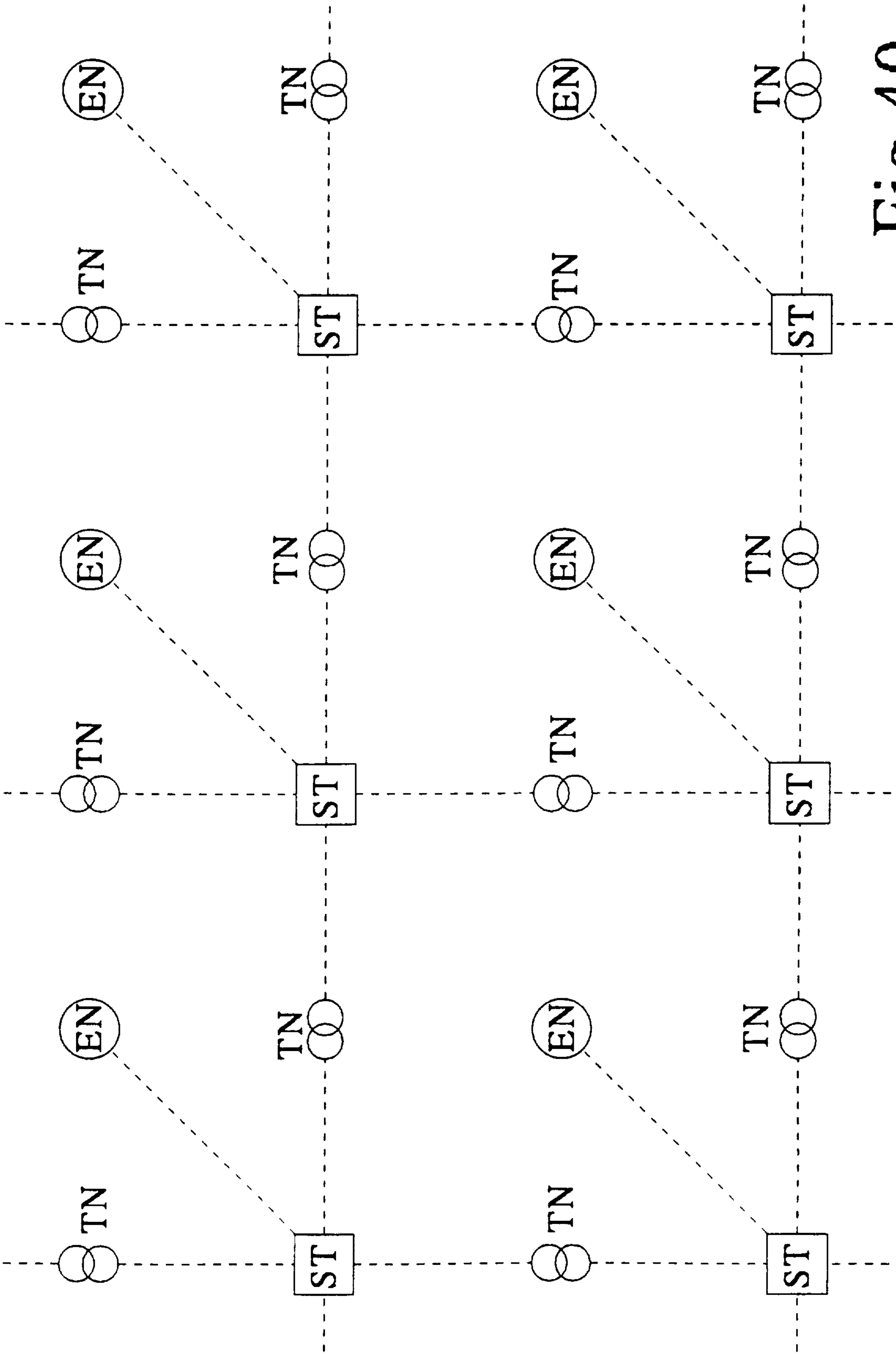


Fig.40

Starnet architecture

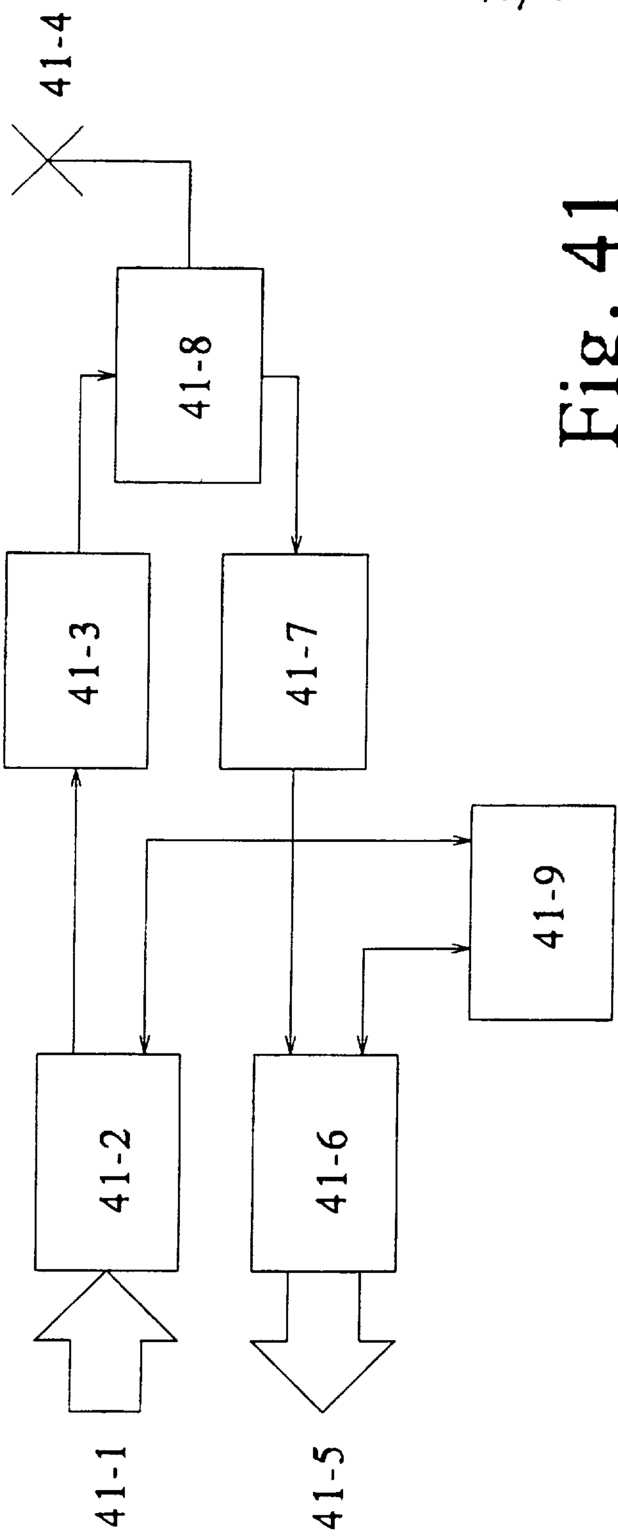


Fig. 41

End node

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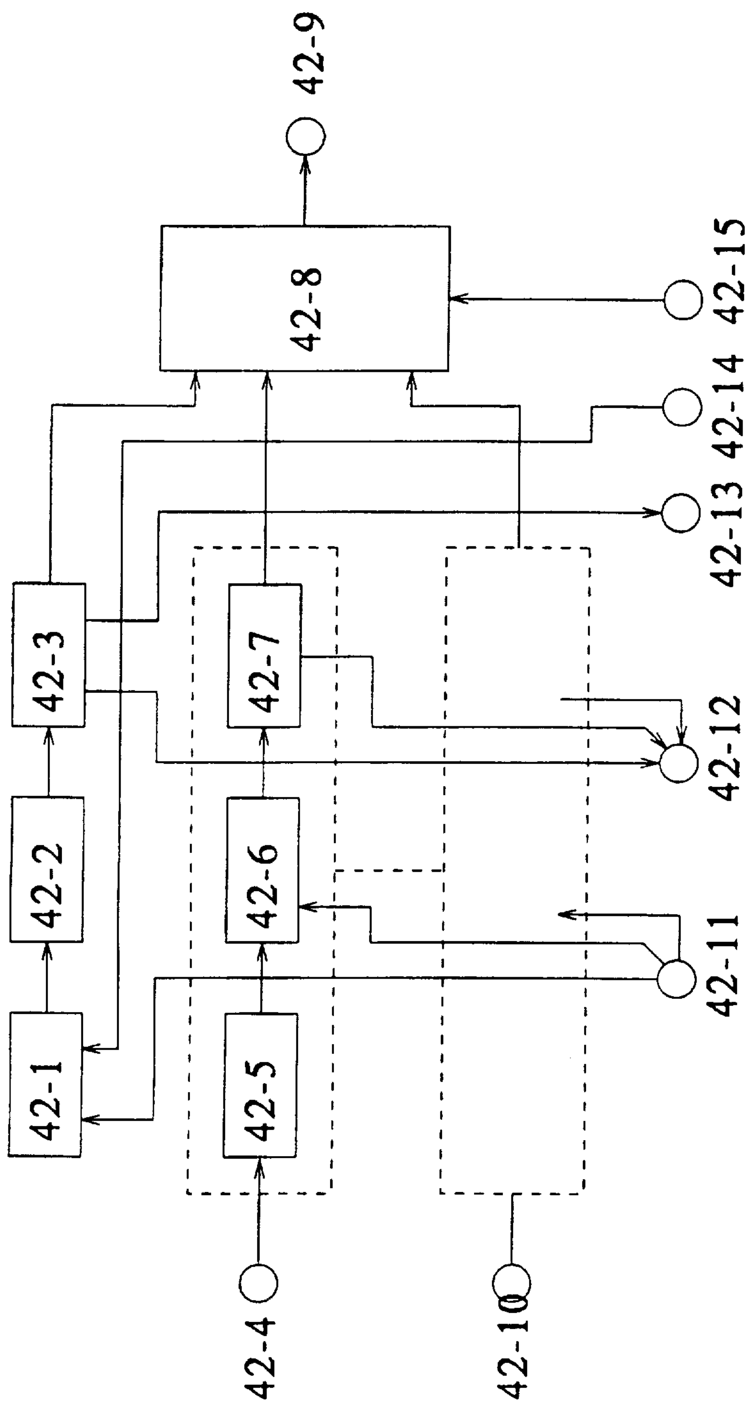

Fig. 42

Input data multiplexer end node

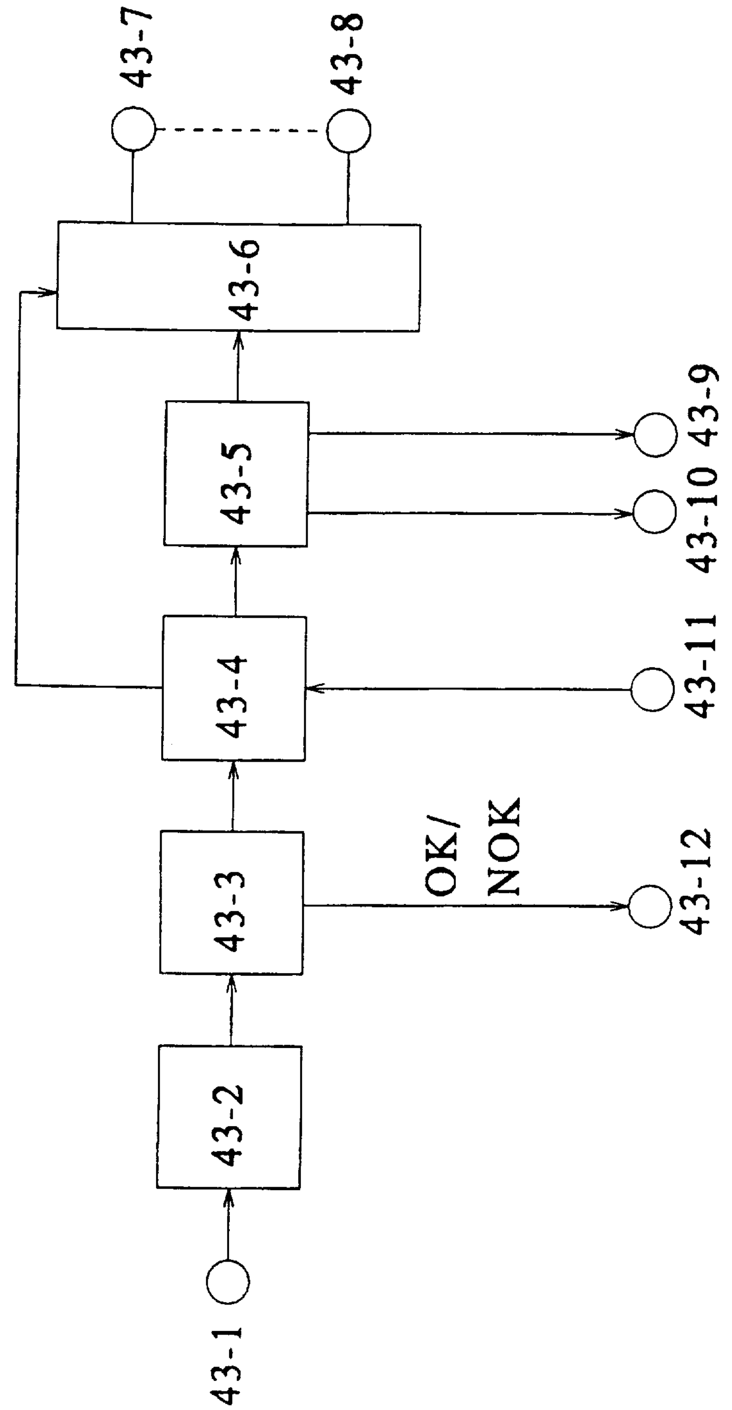

Fig. 43

Output data demultiplexer of end node

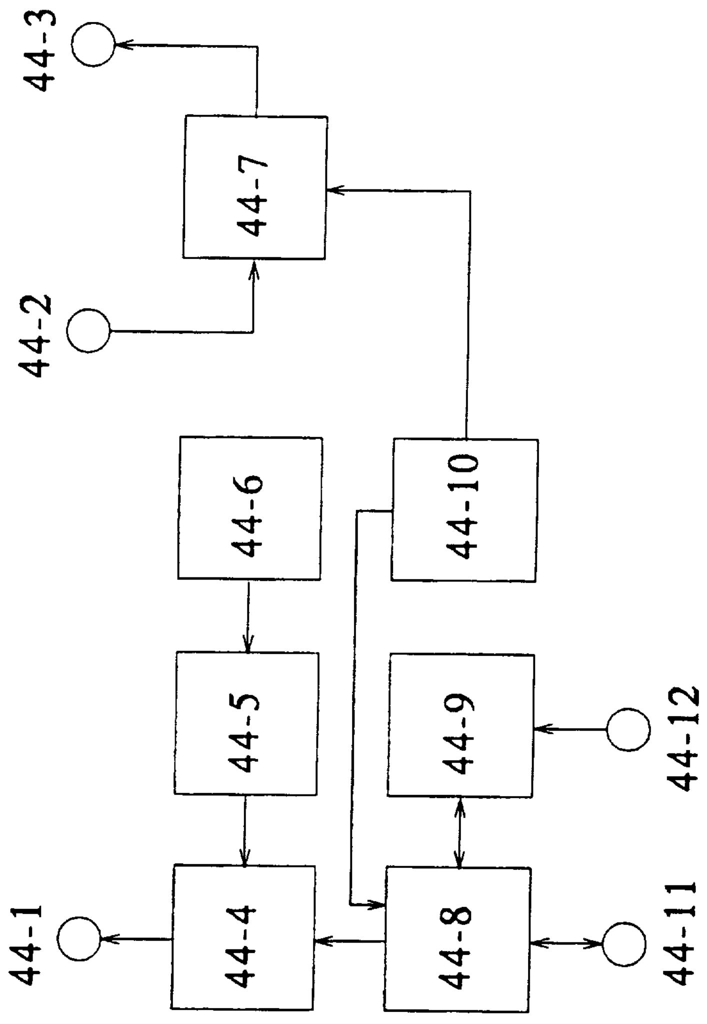

Fig. 44

System control section of end node

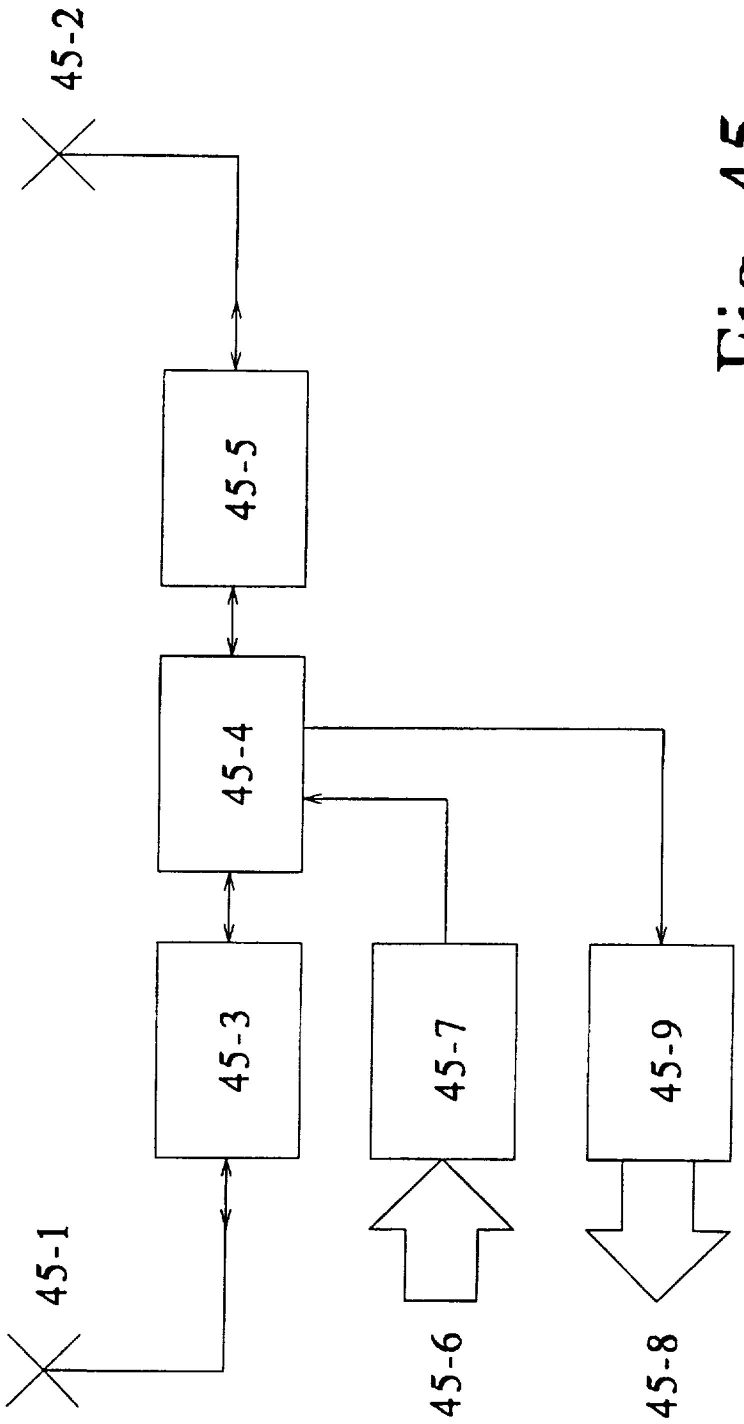

Fig. 45

Transfer node

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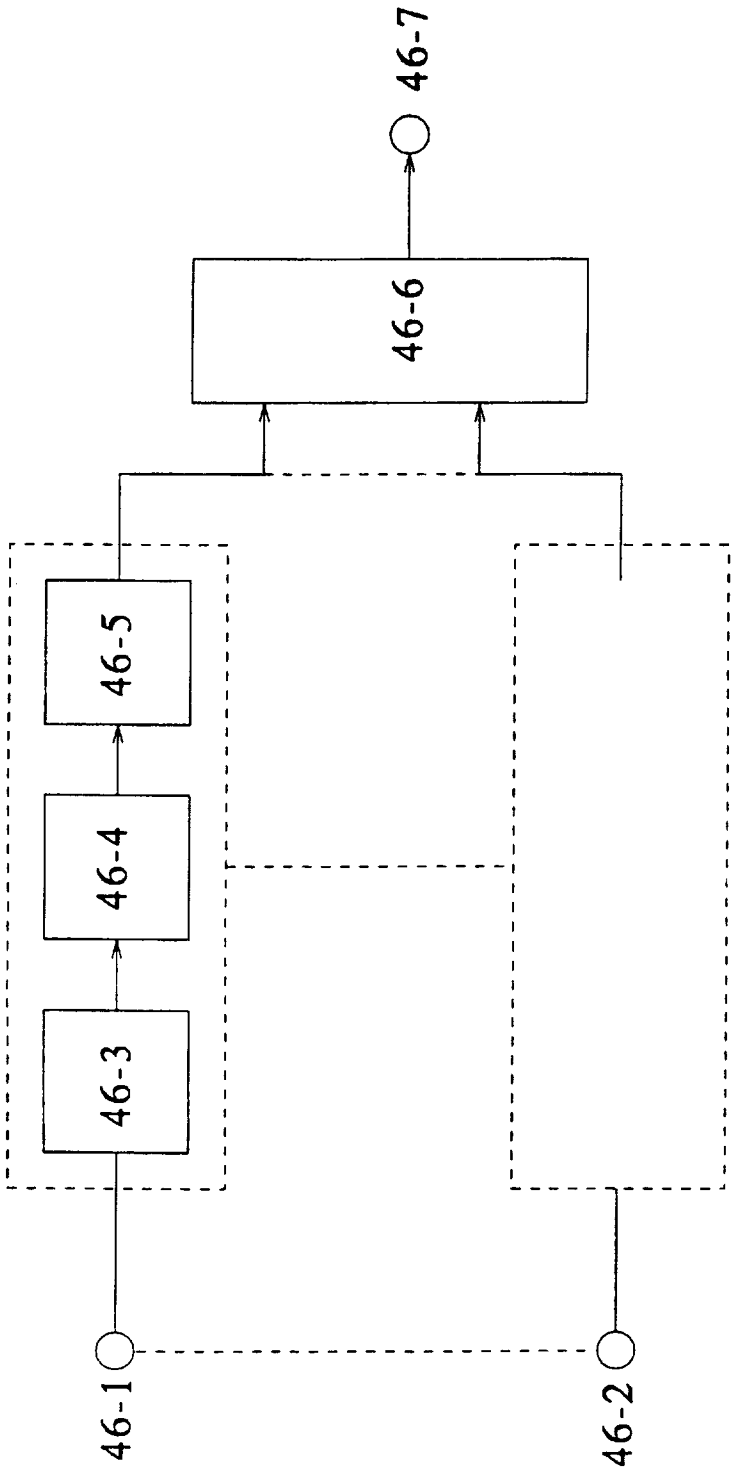

Fig. 46

Input data multiplexer of transfer node

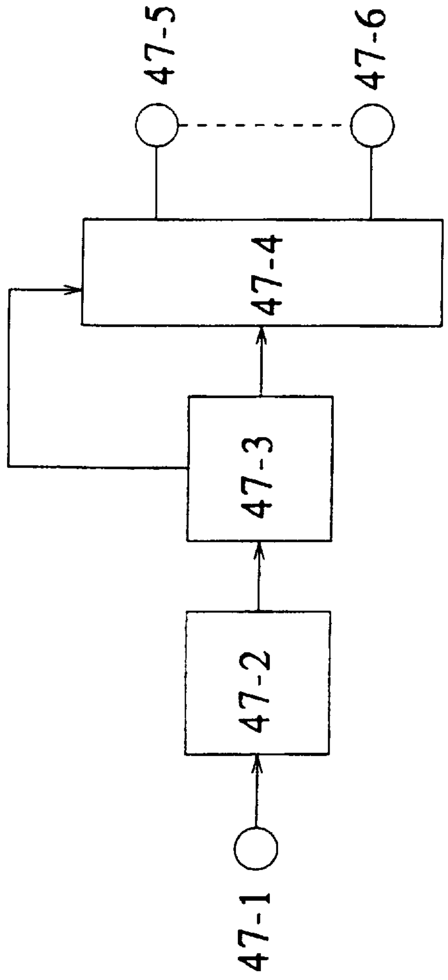

Fig. 47

Output data demultiplexer of transfer node

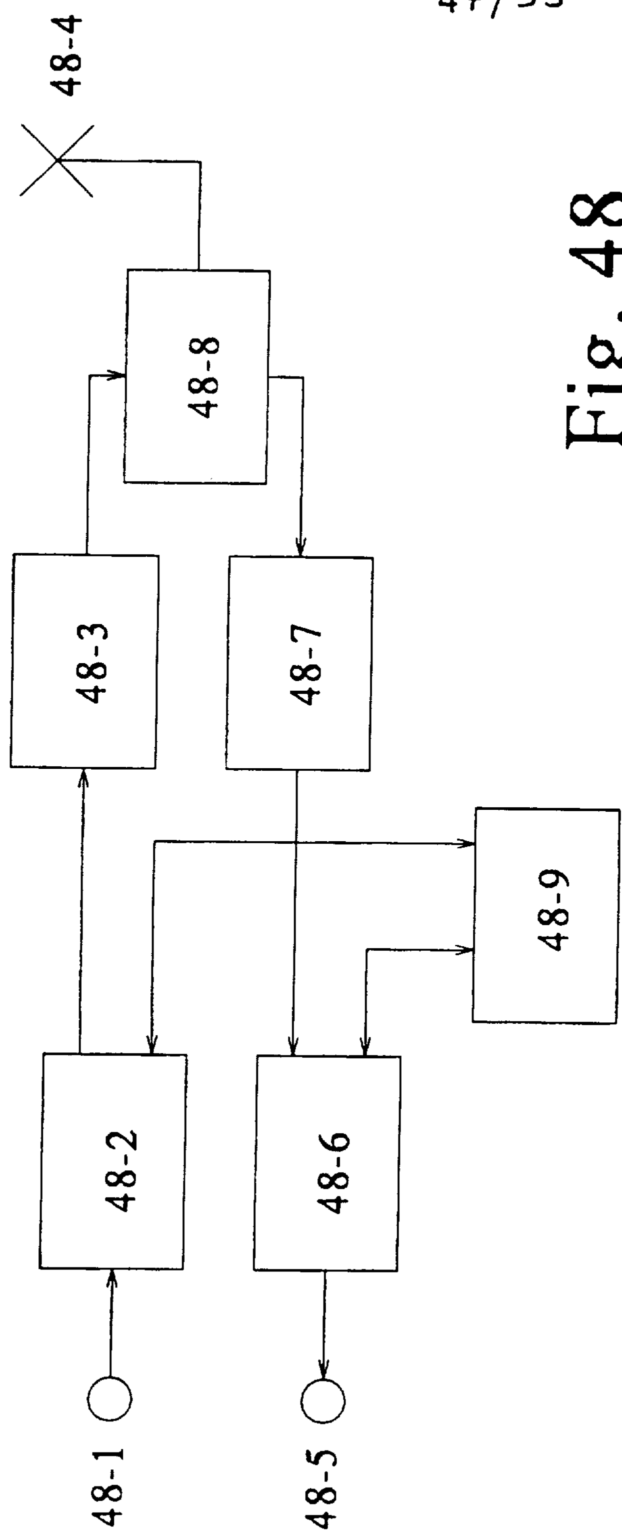

Fig. 48

A link set of a transfer node

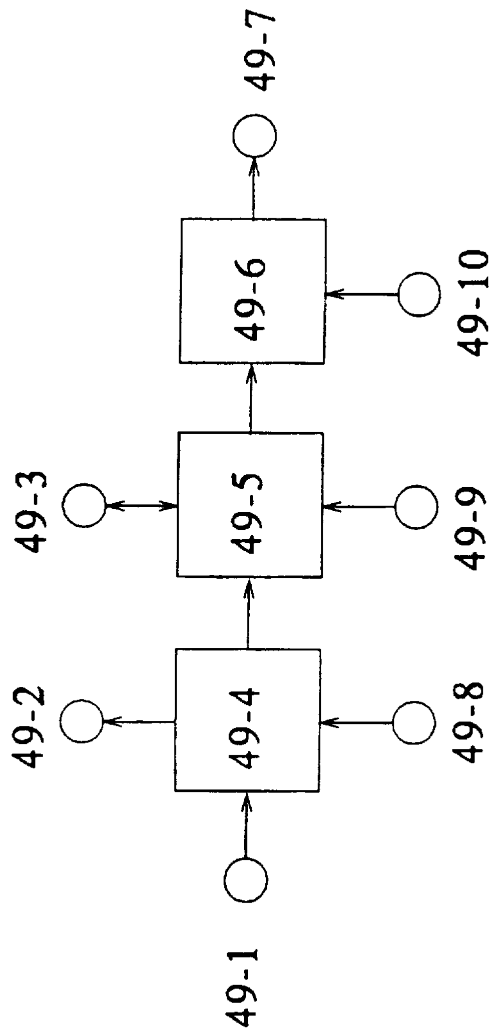

Fig. 49

System control section of end node

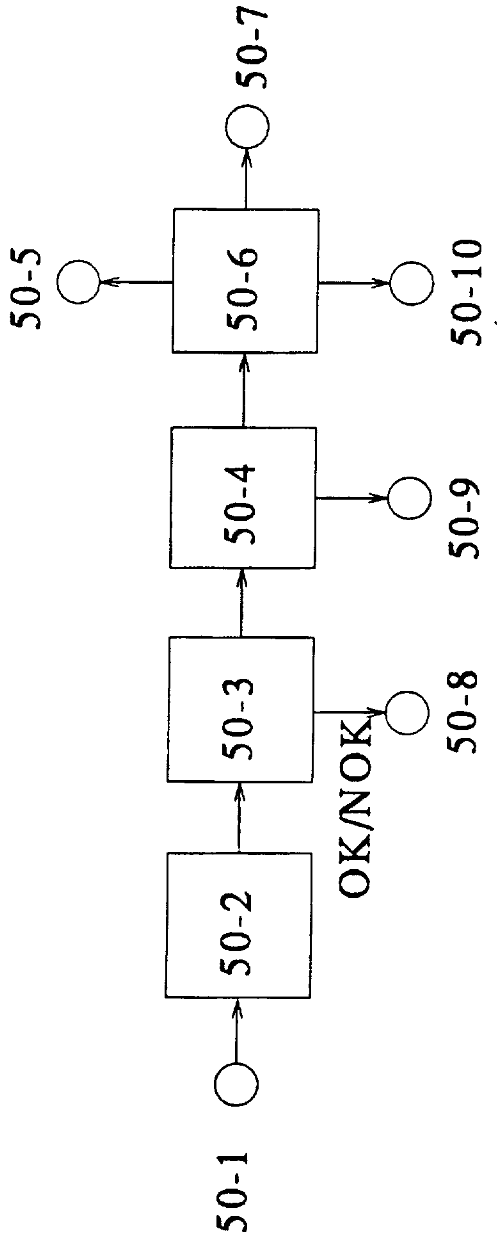

Fig. 50

Output data unit of a link set

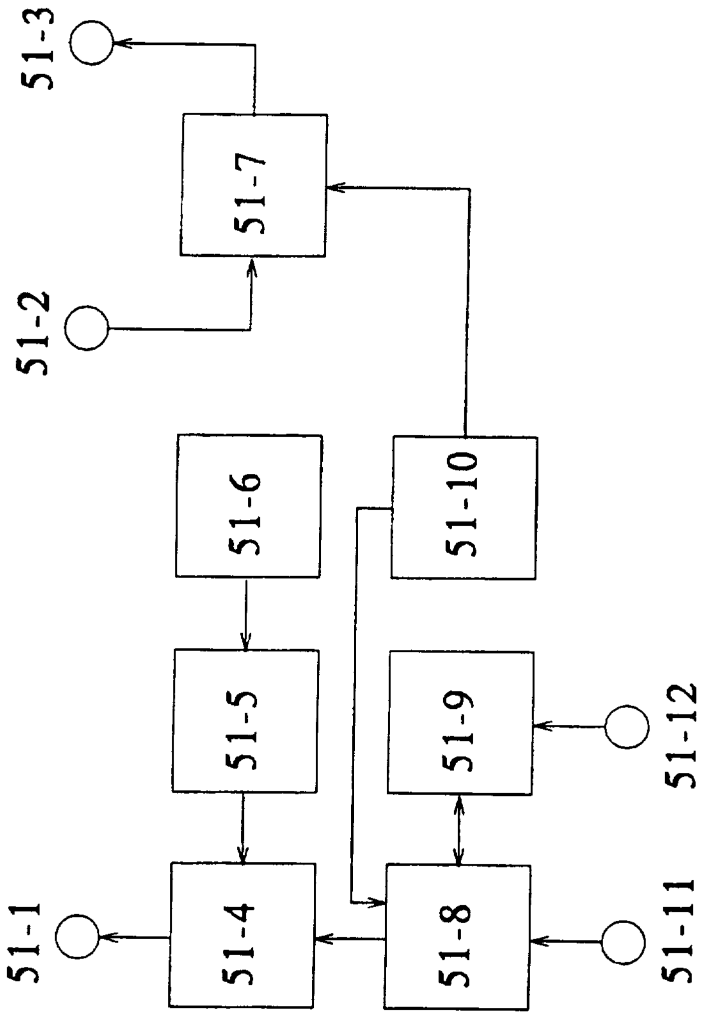

Fig. 51

System control section of a link set

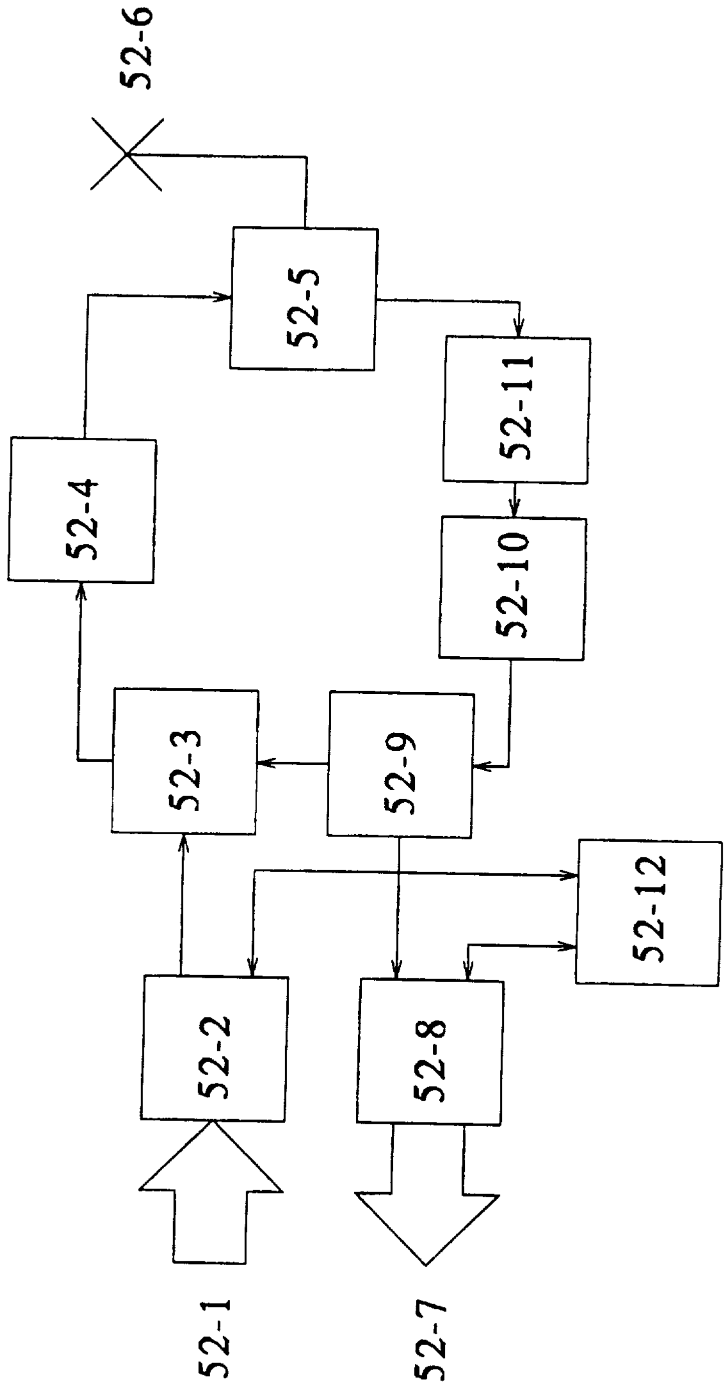

Fig. 52

Star transponder

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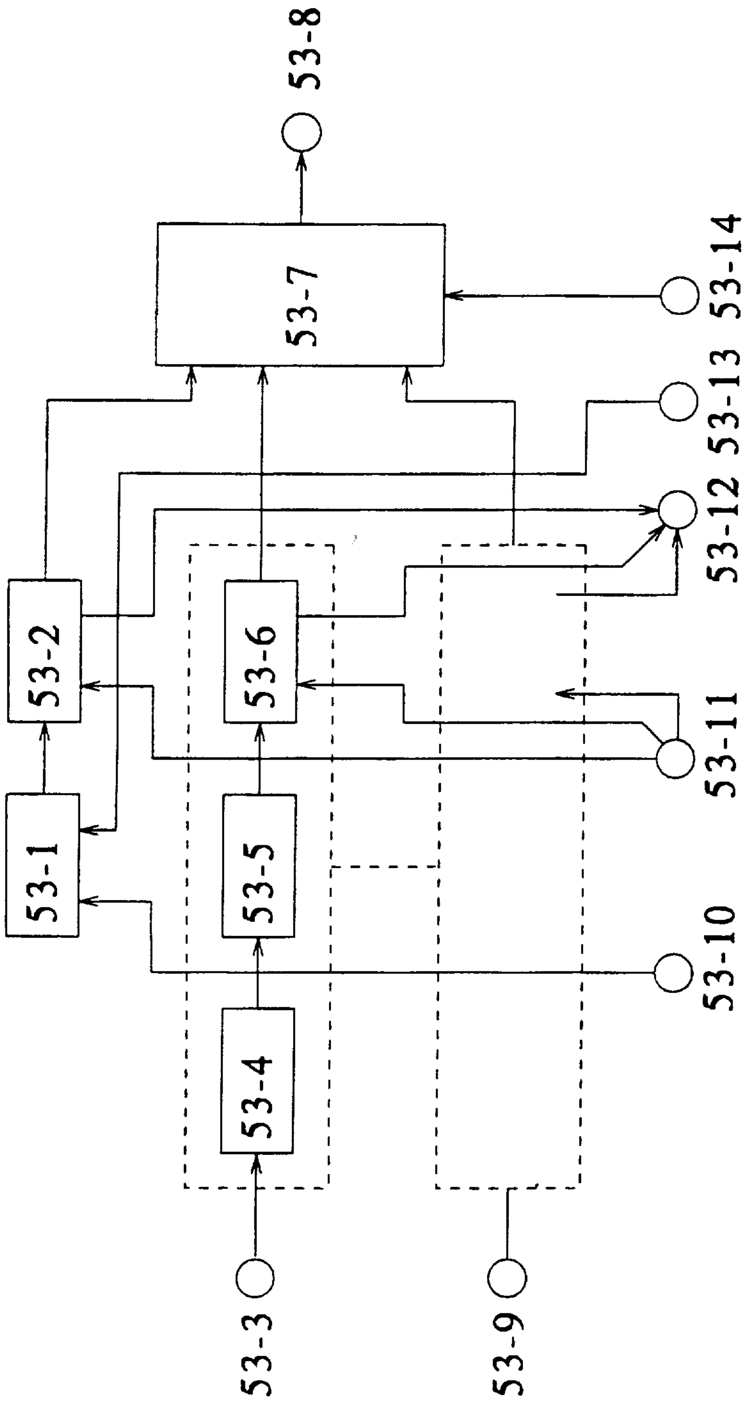

Input data multiplexer of star transponder

Fig. 53

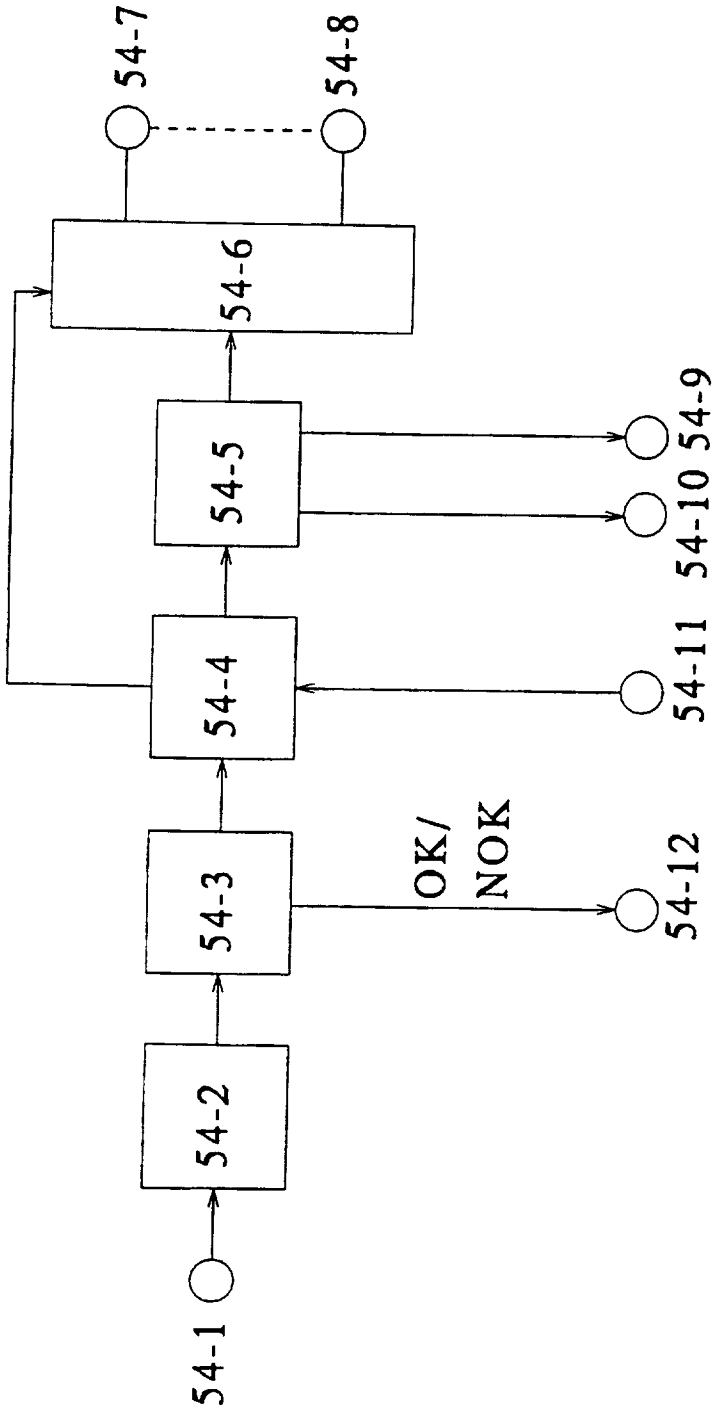

Fig. 54

Output data demultiplexer of star transponder

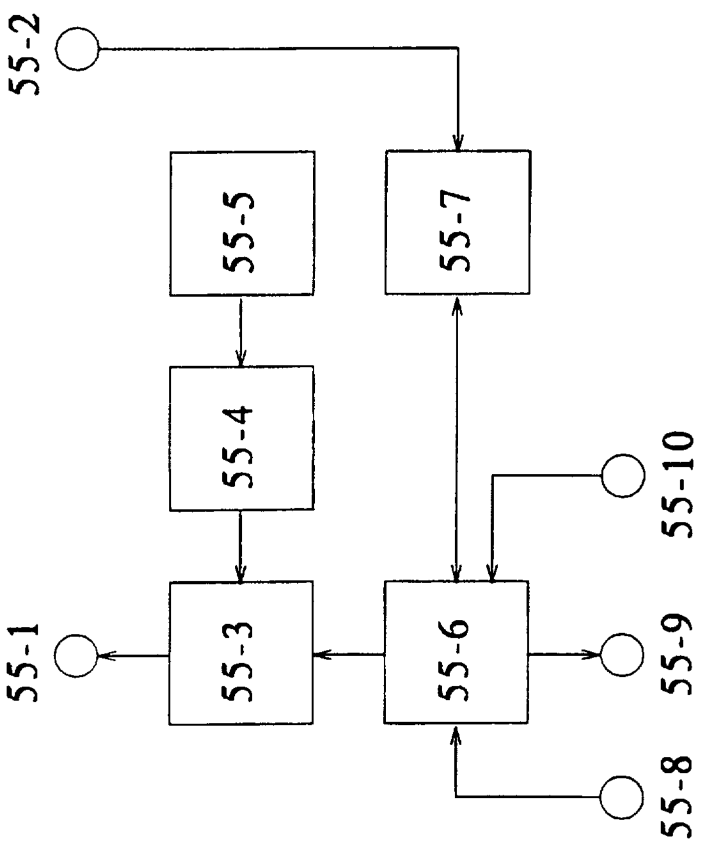

Fig. 55

System control section of a star transponder

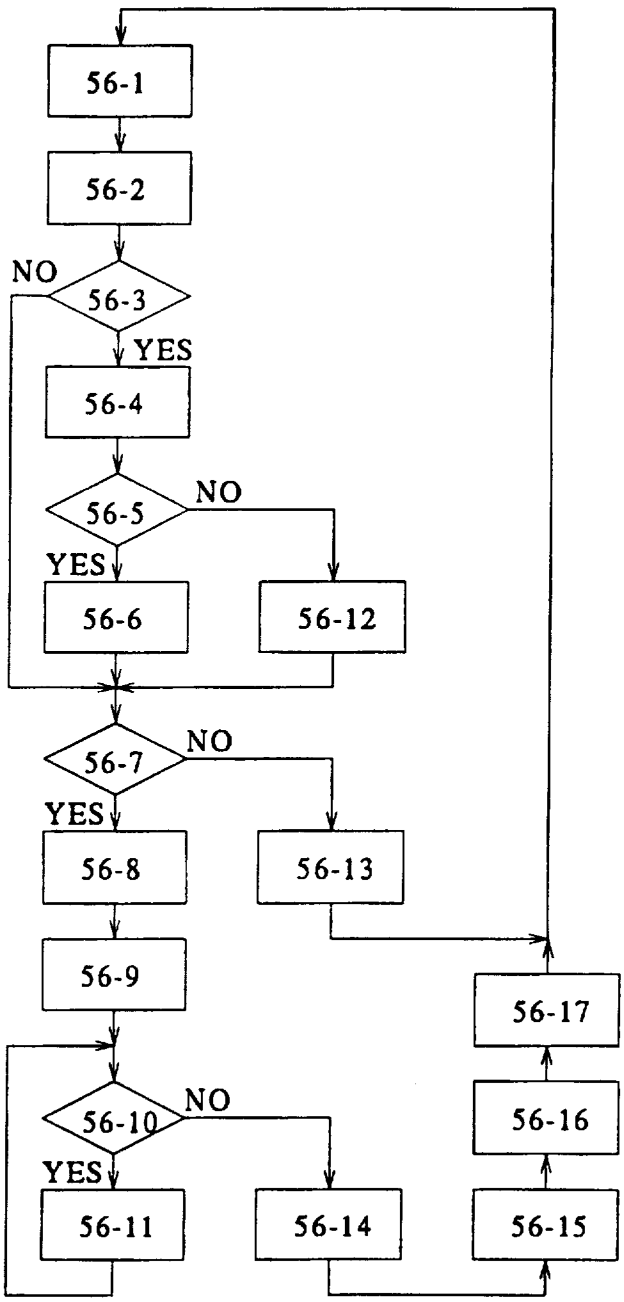

Fig. 56

Time slot data administration transmission of node control system operation

INTERNATIONAL SEARCH REPORT

Inten. nal Application No
PCT/EP 96/03924

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/204

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	EP 0 536 068 A (ALCATEL ESPACE) 7 April 1993 see column 2, line 41 - column 10, line 8 ---	1-8
X	EP 0 371 500 A (NEC) 6 June 1990 see column 2, line 15 - column 4, line 8 ---	9-12
A	EP 0 662 758 A (ERICSSON) 12 July 1995 see claim 1; figures 1,2 ---	13,14
X	US 4 458 247 A (AMITAY) 3 July 1984 see column 1, line 62 - column 2, line 18 ---	15
A	US 5 521 907 A (ENNIS JR. ET AL.) 28 May 1996 see column 1, line 44 - column 2, line 20 --- -/--	15-26

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
24 June 1997	15.07.97

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 5 455 822 A (DIXON ET AL.) 3 October 1995 see claims 1-37 ---	27-40
X	US 5 430 729 A (RAHNEMA) 4 July 1995 see column 2, line 55 - column 3, line 60; figures 1-10 ---	41-53
Y	EP 0 648 027 A (TRW) 12 April 1995 see figures 2-8 ---	54-59
Y	WO 96 26619 A (ERICSSON) 29 August 1996 see claim 1 -----	54-59

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