(54) Title: METHOD AND APPARATUS FOR REGIONAL CELL MANAGEMENT IN A SATELLITE COMMUNICATION SYSTEM

(57) Abstract

In a satellite communication system (10), communication channels are dynamically assigned in real-time based on actual demand using a regionalized channel assignment and reuse scheme. The tradeoff between system capacity and channel interference is optimized through the use of interlocking local regions (81, 82, 83). Satellite communication stations (12) within a radio line-of-sight of each other make up each local region. The communication stations of a local region change as the communication stations move through orbital positions. Channel reuse rules are adapted to system load and demand for services. Each communication station (12) establishes its local region and notifies the other communication stations within its local region whenever it assigns a communication channel to a subscriber unit. Channel assignments within each local region are maintained locally by the defining communication station.
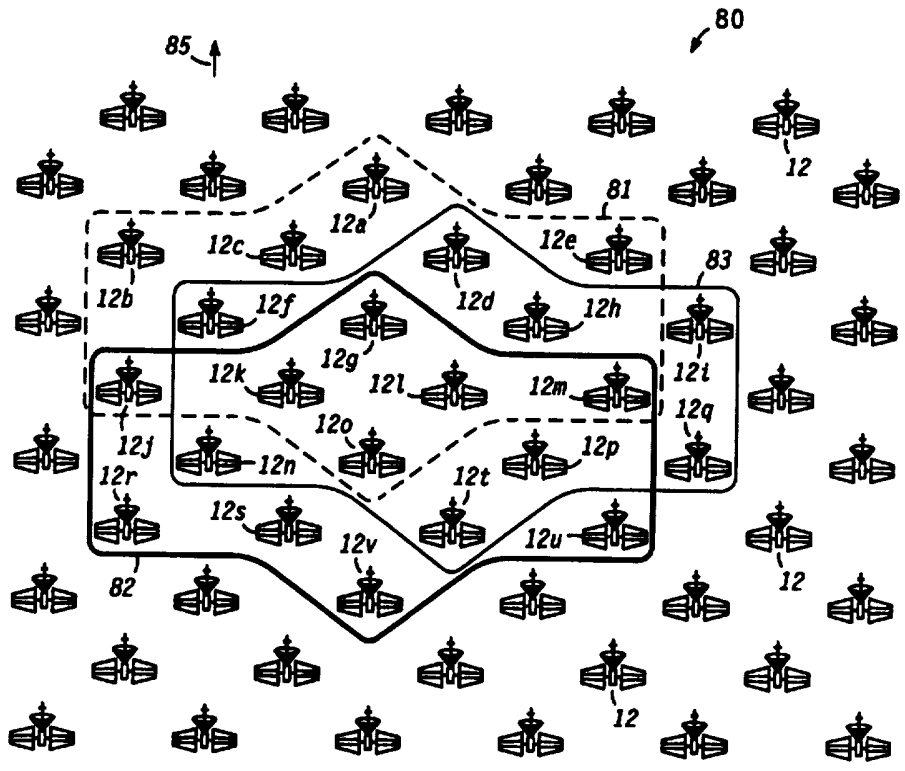
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METHOD AND APPARATUS FOR REGIONAL CELL MANAGEMENT IN A SATELLITE COMMUNICATION SYSTEM

TECHNICAL FIELD OF THE INVENTION

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The present invention relates generally to cellular communication systems that broadcast within multiple antenna beams and communicate with users located within individual beams. More specifically, the present

10 invention relates to satellite communication systems that assign communication channels to users within individual antenna beams.

BACKGROUND OF THE INVENTION

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In cellular communication systems, communication channels are generally assigned to a subscriber unit when an acquisition request is received by the system. The assigned communication channel is chosen so as not to

20 interfere with other communication channels currently in use in the same cell or region that the subscriber unit is located. The assigned communication channel is also chosen so as not to interfere with other communication channels currently in use in neighboring cells.

25 Prior art communication systems that allocate communication channels based on predicted traffic demand suffer from the problem that predicted demand is not very accurate. This results in improper allocation of channels and is inefficient. Real-time channel allocation

30 optimally requires complete knowledge of all channel assignments within the system. Because of propagation delays and limited data-link capacities, real-time knowledge of channel assignments is impractical in a global communication system.

35 In a global communication system that includes satellite communication stations, an optimum approach to channel allocation and assignment requires global knowledge of all channels assigned and presently in use.

An advantage to global knowledge is that indirect interaction between channel assignments on satellites can be planned which allows for maximum utilization of available channel resources. For example, channels

5 assigned over India have an impact on the channels available to be assigned over Europe by restricting the channels that may be assigned in Central-Asia and the Middle-East. Real-time knowledge allows the placement of capacity where the demand is. Disadvantages to this

10 approach include the limited ability to transfer this information in real-time when the communication covers great distances. Other disadvantages to global knowledge approaches include the extensive use of data channels to continually transfer channel assignment information.

15 Thus what is needed are a method and apparatus to dynamically assign communication channels to subscriber units in real-time without complete knowledge of all channel assignments in the system. What is also needed are a method and apparatus for assigning communication

20 channels that have the effect of real-time knowledge without the disadvantages discussed above. Further, what is needed are a method and apparatus that assigns communication channels to subscriber units using a channel reuse scheme that avoids interference with other assigned

25 channels in a satellite-based communication systems.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a highly simplified diagram of a satellite-based communication system with which the present invention may be practiced;

FIG. 2 illustrates a simplified block diagram of a satellite communication station suitable for use in a preferred embodiment of the present invention;

FIG. 3 illustrates a simplified block diagram of a system control station and a terrestrial station suitable for use in a preferred embodiment of the present invention;

FIG. 4 illustrates a low-earth orbit satellite interference scenario;

FIG. 5 shows a simplified example of interlocking local regions defined by satellite communication stations suitable for use in a preferred embodiment of the present invention; and

FIG. 6 shows a flow chart of a channel assignment procedure suitable for use in a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

The present invention provides, among other things, a dynamic, real-time method and apparatus for adaptively assigning channels to subscriber units. In a satellite communication system, communication channels are dynamically assigned in real-time based on actual demand using a regionalized channel assignment and reuse scheme. The tradeoff between system capacity and channel interference is optimized through the use of interlocking local regions. Satellite communication stations within a radio line-of-sight of each other preferably make up each local region. The communication stations comprising a local region may change as the communication stations move through orbital positions. Channel reuse rules are adapted to system load and demand for services. Each communication station establishes its local region and notifies the other communication stations within its local region whenever it assigns a communication channel to a subscriber unit. Channel assignments within each local region are maintained locally by the defining communication station.

A "satellite" is defined herein to mean a man-made object or vehicle intended to orbit earth and includes both geostationary and orbiting satellites and/or combinations thereof including low-earth orbiting (LEO) satellites. A "constellation" is defined herein to mean an ensemble of satellites arranged in orbits for providing specified coverage (e.g., radio communication, photogrammetry, etc.) of portion(s) or all of earth. A constellation typically includes multiple rings (or planes) of satellites and may have equal numbers of satellites in each plane, although this is not essential. As used herein the terms "cell" and "antenna beam" are not intended to be limited to any particular mode of generation and include those created by either terrestrial or satellite cellular communications systems and/or combinations thereof. The present invention is applicable

to systems including satellites having low-earth orbits.
Additionally, it is applicable to orbits having any angle
of inclination (e.g., polar, equatorial or other orbital
pattern).

5   FIG. 1 illustrates a highly simplified diagram of
satellite-based communication system 10 with which the
present invention may be practiced. Communication system
10 uses six polar orbits 14, with each orbit 14 holding
eleven satellite communication stations 12 for a total of

10   sixty-six satellites 12. However, this is not essential
and more or fewer satellites, or more or fewer orbits, may
be used. While the present invention is advantageously
employed when a large number of satellites are being used,
it is also applicable for a small number of satellites.

15   For clarity, FIG. 1 illustrates only a few satellite
communication stations 12.

          For example, each orbit 14 encircles earth at an
altitude of around 780 km, although higher or lower
orbital altitudes may be usefully employed. Due to the

20   relatively low orbits of exemplary satellites 12,
substantially line-of-sight electromagnetic (e.g., radio,
light etc.) transmission from any one satellite or
reception of signals by any one satellite involves or
covers a relatively small area of earth at any instant.

25   For the example shown, satellites 12 travel with
respect to earth at around 25,000 km/hr, allowing
satellite 12 to be visible to a terrestrial station for a
maximum period of approximately nine minutes. Satellite
communication stations 12 communicate with terrestrial

30   stations which may include some number of radio
communication subscriber units (SUs) 26 and earth
terminals (ETs) 24 connected to system control segment
(SCS) 28. ETs 24 may also be connected to gateways (GWs)
22, which provide access to the public switched telephone

35   network (PSTN) or other communications facilities. Only
one each of GWs 22, SCS 28 and SUs 26 are shown in FIG. 1
for clarity and ease of understanding. ETs 24 may be co-
located with or separate from SCS 28 or GW 22. ETs 24

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associated with SCSs 28 receive data describing tracking of satellites 12 and relay packets of control information while ETs 24 associated with GWs 22 only relay data packets (e.g., relating to calls in progress).

5   SUs 26 may be located anywhere on the surface of the earth or in the atmosphere above the earth. SUs 26 are preferably communications devices capable of transmitting data to and receiving data from satellites 12. By way of example, SUs 26 may be a hand-held, portable cellular
10   telephones adapted to communicate with satellites 12. Ordinarily, SUs 26 need not perform any control functions for communication system 10.

Communication system 10 may accommodate any number, potentially in the millions, of subscriber units 26. In
15   the preferred embodiments of the present invention, subscriber units 26 communicate with nearby satellites 12 via subscriber links 16. Links 16 encompass a limited portion of the electromagnetic spectrum that is divided into numerous channels. Links 16 are preferably
20   combinations of L-Band frequency channels and may encompass Frequency Division Multiplex Access (FDMA) and/or Time Division Multiple Access (TDMA) communications or combination thereof. As a minimum, a satellite 12 continuously transmits over one or more broadcast channels
25   18. Subscriber units 26 synchronize to broadcast channels 18 and monitor broadcast channels 18 to detect data messages which may be addressed to them. These data messages include both ring-alerts which notify a subscriber unit that another party desires communication,
30   as well as pages which deliver specific messages. Subscriber units 26 may transmit messages to satellites 12 over one or more acquisition channels 19. Broadcast channels 18 and acquisition channels 19 are not dedicated to any one subscriber unit 26 but are shared by all
35   subscriber units 26 currently within view of a satellite 12.

On the other hand, traffic channels 17 are two-way channels that are assigned to particular subscriber units

26 by satellites 12 from time to time. In the preferred
embodiments of the present invention, a digital format is
used to communicate data over channels 17 - 19, and
traffic channels 17 support real-time communications. At
5   least one traffic channel 17 is assigned for each call,
and each traffic channel 17 has sufficient bandwidth to
support, as a minimum, a two-way voice conversation. To
support real-time communications, a TDMA scheme is
desirably used to divide time into frames, preferably in
10 the 60-90 millisecond range. Particular traffic channels
17 are assigned particular transmit and receive time-
slots, preferably having durations in the 3-10 millisecond
range, within each frame. Analog audio signals are
digitized so that an entire frame's signal is transmitted
15 or received in a single short high speed burst during an
allotted time-slot. Preferably, each satellite 12
supports up to a thousand or more traffic channels 17 so
that each satellite 12 can simultaneously service a like
number of independent calls.

20   Satellites 12 communicate with other nearby
satellites 12 through cross links 23. In the preferred
embodiment, cross links 23 are Ka-band frequency channels.
Thus, a communication from a subscriber unit 26 located at
any point on or near the surface of the earth may be
25 routed through the constellation of satellites 12 to
within range of substantially any other point on the
surface of the earth. A communication may be routed down
to a subscriber unit 26 on or near the surface of the
earth from a satellite 12 using a subscriber link 16.
30 Alternatively, a communication may be routed down to or up
from any of many ETs 24, of which FIG. 1 shows only two,
through earth links 15. ETs 24 are preferably distributed
over the surface of the earth in accordance with geo-
political boundaries. In the preferred embodiments, each
35 satellite 12 may communicate with up to four ETs 24 and
over a thousand subscriber units 26 at any given instant.
       SCS 28 monitors the health and status of system
communication nodes (e.g., GWs 22, ETs 24 and satellites

12) and desirably manages operations of communication
system 10. One or more ETs 24 provide the primary
communications interface between SCS 28 and satellites 12.
ETs 24 include antennas and RF transceivers and preferably
5   perform telemetry, tracking and control functions for the
constellation of satellites 12.

GWs 22 may perform call processing functions in
conjunction with satellites 12 or GWs 22 may exclusively
handle call processing and allocation of call handling
10   capacity within communication system 10. Diverse
terrestrial-based communications systems, such as the
PSTN, may access communication system 10 through GWs 22.

With the example constellation of sixty-six
satellites 12, at least one of satellites 12 is within
15   view of each point on earth's surface at all times (i.e.,
full coverage of the earth's surface is obtained).
Theoretically, any satellite 12 may be in direct or
indirect data communication with any SU 26 or ET 24 at any
time by routing data through the constellation of
20   satellites 12. Accordingly, communication system 10 may
establish a communication path for relaying data through
the constellation of satellites 12 between any two SUs 26,
between SCS 28 and GW 22, between any two GWs 22 or
between SU 26 and GW 22.

25   FIG. 2 illustrates a simplified block diagram of
satellite communication station 12 suitable for use in a
preferred embodiment of the present invention.
Preferably, all satellites 12 within system 10 (see FIG.
1) include equipment as illustrated by the block diagram
30   of FIG. 2. Satellite 12 includes cross-link transceivers
33 and associated antennas 31. Transceivers 33 and
antennas 31 support cross-links to other nearby satellites
12. Earth-link transceivers 35 and associated antennas 37
support earth-links to communicate with earth terminals 24
35   (FIG. 1). Subscriber-link transceivers 30 and associated
antennas 32 support subscriber units 26 (FIG. 1).
Preferably, each satellite 12 may simultaneously support a
link for up to several thousand or more of subscriber

units 26 (FIG. 1). Of course, those skilled in the art
will appreciate that antennas 31, 37, and 32 may be
implemented either as single multi-directional antennas or
as banks of discrete antennas. It is desirable that each
5   subscriber-link antenna 32 be a phased array antenna
capable of accessing many antenna beams simultaneously.

A controller 34 couples each of transceivers 33, 35,
and 30 as well as to a memory 36 and a timer 38.
Controller 34 may be implemented using one or more
10   processors. Controller 34 uses timer 38 to maintain,
among other things, the current date and time. Memory 36
stores data that serve as instructions to controller 34
and that, when executed by controller 34, cause satellite
12 to carry out procedures which are discussed below. In
15   addition, memory 36 includes variables, tables, and
databases that are manipulated during the operation of
satellite 12.

Subscriber-link transceivers 30 are desirably multi-
channel FDMA/TDMA transceivers capable of transmitting and
20   receiving on all different selectable frequencies during
particular, selectable, time-slots as directed by
controller 34. Subscriber-link transceivers 30 contain
multi-channel radios having a sufficient number of
channels to provide the desired number of transmission and
25   reception frequencies for signal access and control and
for the user voice and/or data. Controller 34 may provide
for allocation of the frequency and time-slot assignments,
antenna beam-to-antenna beam hand-off and other overhead
and management and control functions. Subscriber-link
30   transceivers 30 desirably provide for transmission and
reception on any frequency channel set so that each
subscriber-link transceivers 30 may, if needed, utilize
the entire spectral capacity of all frequency channel sets
by having the capability to handle all frequency and time-
35   slot assignments.

FIG. 3 illustrates a simplified block diagram of
system control station 45 and terrestrial station 48
suitable for use in a preferred embodiment of the present

invention. Control station 45 and terrestrial station 48
are desirable part of SCS 28 (FIG. 1) and ET 24 (FIG. 1)
respectively. Control station 45 comprises processor 40
coupled to associated storage medium 42 (e.g., random
5   access memory or RAM, other semiconductor or magnetic
read-write memory devices, optical disk, magnetic tape,
floppy disk, hard disk etc.) via link 41. Terrestrial
station 48 includes antenna 49 coupled to transmitter 43
and receiver 47. Transmitter 43 and receiver 47 are
10   coupled to processor 40 via links 44 and 46, respectively.
Processor 40 desirably carries out procedures exemplified
below and described in the associated text. For example,
in addition to performing other tasks as appropriate,
processor 40 desirably stores results from such procedures
15   in storage medium 42. Transmitter 43 and/or receiver 47
transmit messages to and/or receive messages from
satellites 12.

     Processor 40 generally controls and manages user
access, message reception and transmission, channel set-
20   up, radio tuning, frequency and time-slot assignment, and
other cellular radio communication and control functions
not managed or provided for by controller 34 (FIG. 2).
Among other things, processor 40 and/or controller 34
(FIG. 2) desirably executes procedures to allow user
25   access to communication system 10. This may include
procedures for protocols for channel setup and other
associated functions as discussed below.

     FIG. 4 illustrates a low-earth orbit satellite
interference scenario. Direct interference and a chain
30   reaction effect of channel assignment drive the need for
real-time global knowledge in an optimum channel
allocation process. Direct interference may occur when
channels in use on a particular satellite interfere with
channels on other satellites which are within a line-of-
35   sight of each other. This is described in more detail
below.

     The chain reaction effect of channel assignment
occurs when a satellite assigns a channel to a subscriber

unit. The available channels on neighboring satellites within its line-of-sight are limited to non-interfering channels. This limitation restricts the channels that may be assigned by other satellites not in the line-of-sight of the original assigning satellite. Thus, the assignment of a channel by a satellite has consequences on channel availability on all other satellites in the entire constellation.

Referring to FIG. 4, satellites 52, 62 and 72 are communication satellites preferably in a low-earth orbit analogs to satellite communication stations 12 (FIGs. 1 and 2). Satellites 52, 62 and 72 communicate with subscriber units analogs to SU 26 (FIG. 1). As shown, satellite 52 has established a communication link with subscriber unit 56 over communication link 53; satellite 62 has established a communication link with subscriber unit 66 over communication link 63; and satellite 72 has established a communication link with subscriber unit 76 over communication link 73. Subscriber units 56, 66 and 76 are shown located on the surface of earth 50. Satellite 62 is within a radio line-of-sight of satellites 52 and 72. Therefore, satellite 62 can interfere with RF communications of satellites 52 and 72. Satellites 52 and 72 are not within a radio line-of-sight of each other and therefore cannot interfere with the RF communications of each other. In other words, radio frequency signals can directly be sent from satellites 62 to either satellite 52 or satellite 72, but radio frequency signals cannot be sent between satellites 52 and 72.

Satellite 62, when communicating with subscriber unit 66, has interference paths 64 and 65 to subscriber units 76 and 56 respectively. Satellite 52 has interference path 54 with subscriber unit 66. To prevent interference with satellite 62, satellites 52 and 72 must choose communication channels for communication links 53 and 73 that will not interfere with communication link 63. As a result of choosing non-interfering channels, the choice of channels on satellite 52 is constrained by the choice of

channels on satellite 62, and vice versa. The choice of
channels on satellite 52 is also constrained by channels
assigned by satellite 72, and vice versa. Thus, an
assignment of channels by one satellite produces chain
5   reaction limiting the channels available for assignment by
other satellites.

       An optimum channel assignment requires real-time
knowledge of all channels in use by the entire system
(i.e., global knowledge). Global knowledge is desirable
10   because of the chain reaction effect of channel assignment
described above. True real-time knowledge of all channel
assignments in a world-wide communication system is
impossible due to finite propagation delay of
communication signals. Near real-time knowledge is
15   impractical because excessive status reporting would be
required which would require significant communication
resources. The allocation of communication channel
resources based on expected or predicted traffic is one
attempt at a near-optimum solution. However, the
20   uncertainty in predicted traffic may result in significant
inefficiency. As described below, near real-time channel
assignment information in a local area provides a near-
optimum solution to channel assignment.

       FIG. 5 shows a simplified example of interlocking
25   local regions defined by satellite communication stations
suitable for use in a preferred embodiment of the present
invention. Satellites of the constellation (see FIG. 1)
are organized into a plurality of interlocking local
regions comprised of several nearby satellites. Each
30   satellite obtains most of the required knowledge for
correct channel assignments in near real-time without the
need for each satellite to have knowledge of all the
channel assignments in the entire system. A near-optimum
solution is obtained with knowledge of channel assignments
35   of the local region.

       FIG. 5 shows portion 80 of a constellation of
satellites 12. In the preferred embodiment, satellites 12
are in a low-earth orbit surrounding the earth, and as a

result, satellites 12 are not located in a planar
configuration as shown on a sheet of paper, but are
located on a spherical surface. Each satellite 12
establishes it own local region. Local regions preferably
5   include all satellites that are within the radio horizon,
or radio line-of-sight of each other. For example,
satellite 12g defines local region 81. Local region 81
includes satellites 12a through 12h, 12j through 12m, and
12o. These thirteen satellites in local region 81 are
10 within a radio line-of-sight of satellite 12g. Satellite
12i is not within radio line-of-sight of satellite 12g,
and therefore is not included in satellite 12g's local
region. Satellite 12i is below the radio horizon of
satellite 12g. Local region 82, for example, is defined
15 by satellite 12o, and includes satellites 12g, 12j through
12m, 12n, 12o, 12p, 12r through 12v. Local region 83, for
example, is defined by satellite 12ℓ and includes
satellites 12d, 12f through 12i, 12k though 12q, and 12t.

As defined, all satellites in a local region are
20 within radio line-of-sight of each other. Satellites
outside a local region are below a radio line-of-sight of
each other. For the example shown in FIG. 5, only three
local regions are shown for clarity, although in the
preferred embodiment, every satellite defines its own
25 local region.

The number of satellites in any given local region
will depend on several factors, including the number of
satellites in the constellation, the type of orbit, the
orbital positions and height of the satellites, and the
30 relative positions of the satellites. As those of skill
in the art will understand, when all satellites are in
polar orbits, for example, the number of satellites in a
local region increases as the satellites approach the
poles. Likewise, when all satellites are in polar orbits,
35 the number of satellites in a local region decreases as
the satellites approach the equator. In a preferred
embodiment, satellites 12 are in polar orbits. In this
situation, satellites 12 are moving in flight path

direction 85 which is directed toward or away from one of
earth's poles. In the preferred embodiment discussed in
FIG. 1, there are sixty-six satellites in a low-earth
polar orbit. Although the examples discussed herein are
5   for polar-orbiting satellites, the present invention is
applicable to any orbiting satellite communication system
where satellites are within a radio line-of-sight of each
other.

In one embodiment of the present invention, local
10 regions are defined to include only satellites over
populated areas that are within line-of-sight of the
satellite defining the local region. When this embodiment
includes satellites in polar orbits or near-polar orbits,
the large number of satellites that come into view when
15 the defining satellite is over a polar region are excluded
from the local region.

In another embodiment of the present invention, each
local region contains a fixed number of satellites. The
satellites comprising the local regions are determined
20 when the defining satellite is between a maximum north and
south latitude, preferably around fifty-five degrees
latitude. An advantage to this embodiment is that the
processing required onboard each satellite is simplified.

As can be seen by the example of FIG. 5, each
25 satellite will be a member of several local regions. A
satellite will be a member of the local region that it
defines, and it will be a member of local regions defined
by neighboring satellites. Regardless of the number of
local regions that a satellite belongs to, each satellite
30 is only required to have knowledge of channel assignments
by members of its own local region. For example,
satellite 12g (FIG. 5) is a member of local regions 81, 82
and 83, but is only required to have knowledge of channel
assignments by satellites of local region 81, because
35 local region 81 has been defined by satellite 12g.
Satellite 12m, for example, is also a member of local
regions 81, 82 and 83, but is not required to have
knowledge of all the satellites in any of those local

regions shown, because satellite 12m is not the defining
satellite for either local regions 81, 82 or 83.
Satellite 12m would be a defining satellite for its own
local region, not shown.

5   In the preferred embodiment, channel assignments are
allocated to subscriber units on the basis of the channel
assignments made by other satellites in its local region.
Preferably, a communication channel assigned by a defining
satellite is non-interfering with channels assigned by
10   other satellites within its local region.

In order to make channel assignments, knowledge of
all channel assignments within a satellite's local region
is preferable. Whenever a channel is assigned to a
subscriber unit, the assigning satellite sends a message
15   to all satellites in its local region. The message
includes at a minimum, the specific communication channel
assigned. In the preferred embodiment of FIG. 1, channel
assignment messages between satellites are sent over links
21 and 23. The channel assignment method preferably uses
20   the current local demand, current local distribution of
users, and the set of channels that have already been
assigned to make new assignments that provide acceptable
interference performance. In the preferred embodiment
where a combination of FDMA/TDMA channels are used, an
25   example of a non-interfering communication channel
includes a time-slot of a frequency channel not assigned
to another subscriber unit.

The global effect of channel assignment is captured
by use of interlocking local regions. Each satellite is
30   not required to maintain or have true or real-time global
knowledge of all channel assignments within the entire
constellation. Satellites never exchange channel
assignment information with satellites outside their local
region. Satellites receive direct information from the
35   satellites whose channels can interfere with them, and the
chain reaction effect is captured because the regions
interlock.

The interlocking effect can be described as follows:
When a first satellite, having defined a first local
region, assigns a channel, it indicates this to all other
satellites within its local region. The choices of

5   channel assignments for all the satellites within its
local region becomes limited because the satellites within
the local region can only assign non-interfering channels.
Thus, a limited pool of available channels results for
each satellite within the first local region. When one of

10 the other satellites (a second satellite that has defined
a second local region) in the first local region assigns a
channel from this limited pool of channels, it informs all
satellites within the second local region of this
assignment. This limits their choices of available

15 channels for all satellites within the second local
region. Since the second local region includes satellites
not within the first local region, an assignment by the
first satellite has an indirect effect on the pool of
channels available outside of its own local region. This

20 same effect is seen when channels are assigned on the
basis of true, real-time global knowledge of all channel
assignments within a constellation of satellites.

FIG. 6 shows a flow chart of channel assignment
procedure 90 suitable for use in a preferred embodiment of

25 the present invention. In the preferred embodiment,
procedure 90 is performed by satellite communication
station 12 (FIGs. 1, 2 and 5). In task 92, a local region
is established for the defining satellite. The local
region preferably includes all satellites within a radio

30 line-of-sight of the defining satellite communication
station. In one embodiment, a local region definition
table 91 is used. The local region definition table is
preferably uploaded to the satellite by SCS 28 (FIG. 1)
and includes a list of all satellites within a local

35 region. When the satellites are moving in orbits,
different local regions are defined for each orbital
position of a satellite. For example, when the satellites
are in polar orbits, there may be more satellites within a

local region near the poles than near the equator.
Preferably, there are different tables for each orbital
position of the defining satellite.

In another embodiment, a local region is established
5   by the receipt of data, such as channel assignments
broadcasted by other satellites within line-of-sight. In
this embodiment, satellites may be given different time-
slots in which to transmit channel assignments. In this
way, channel assignment messages will not interfere with
10   each other.

In task 94, procedure 90 waits for an interrupt.
Either a request for a channel assignment for a subscriber
unit (from task 95) or a region time-out (from task 97)
causes an interrupt.

15   In task 95, a request for a channel assignment is
received. The request indicates that a subscriber unit
needs to have a communication channel assigned to it. A
request may come from a subscriber unit, or alternatively
a gateway or somewhere else in the communication system.
20   The specific method of channel requests and acquisition is
not important to the present invention.

In task 95, channel assignment requests may also come
from hand-off requests. Hand-offs occur when a subscriber
unit presently communicating on a traffic channel is
25   switched to another antenna beam (beam-to-beam hand-offs).
In a preferred embodiment, many more channel assignments
are for hand-offs because the satellites are moving
rapidly with respect to the surface of the earth and
subscriber units must be transferred to the next antenna
30   beam. Desirably, as a subscriber switches between antenna
beams, and between satellites, the same channel is used in
the subsequent antenna beam. Those of skill in the art
will understand that many methods are suitable for channel
hand-off and do not need to be described herein.

35   Task 97 generates region time-outs. As a satellite
moves through different orbital positions through each
orbit, different satellites comprise its local region.

Thus, each orbital position should have a different local
region of satellites established.

In task 96, if the interrupt was created by a request
for channel assignment (task 95), task 98 is executed. If
5   the interrupt was created by a region time-out, procedure
90 loops back to task 92 to establish a new local region
for the next orbital position of the satellite.

In task 98, the channels that have been assigned by
satellites within its local region are determined. The
10 satellite receives messages (task 99) from members of it's
local region so it knows which channels are currently in
use by other satellites within its local region.   In the
preferred embodiment, a list of currently assigned
channels with its local region is maintained by the
15 defining satellite and stored in its memory.

In task 100, a non-interfering channel is assigned to
the subscriber unit from channels allocated to the
communication system. The non-interfering channel is
chosen based on several factors including antenna pattern
20 isolation, and the effects of propagation delay and
Doppler frequency shift on currently assigned channels.
The precise method of selecting a non-interfering channel
is not important for the present invention. In the
preferred embodiment, non-interfering channels are
25 assigned based on a minimum channel reuse distance rule
based on the antenna beam angular separation. The
probability of two satellites of a local region assigning
the same channel simultaneously is reduced by the rapid
communication of channel assignments to satellites within
30 their local regions. Furthermore, in the preferred
embodiment, a large channel-set having up to several
thousand non-interfering channels is allocated to the
communication system. The large channel-set reduces the
probability of two satellites simultaneously assigning the
35 same channel within a local region.

In one embodiment of the present invention, pre-
planned assignment pools based on geographically fixed
regions are used for selecting available channels. In

another embodiment, pre-planned assignment pools of
channels are preferred by different satellites for
assignment. Both of these embodiments reduce the
possibility of two satellites simultaneously assigning the
5   same channel within a local region.

In task 102, other satellites within the defining
satellite's local region are notified that the channel
assigned in task 100, has been assigned to a subscriber
unit. This notification message is preferably transmitted
10 directly to satellites within the defining satellite's
local region over cross-links 21 and 23 (FIG. 1). As
discussed above depending on how the local region is
defined, in one embodiment the receipt of notification
messages can be used by the receiving satellite to define
15 its local region.

In task 104, a message is sent to the subscriber unit
that a traffic channel has been assigned for
communication. Transceivers in the satellite and the
subscriber unit are switched to communicate with the
20 subscriber unit over the assigned traffic channel rather
that an acquisition or broadcast channel. After the
traffic channel is assigned to the subscriber unit,
procedure 90 loops back and repeats task 94 to wait for
another channel assignment request or region time-out.

25   In a preferred embodiment of the present invention,
each satellite communication station of the constellation
performs procedure 90 on a continual basis.

An advantage to the present invention is that the
global effect of channel assignment is captured by use of
30 interlocking local regions. Each satellite is not
required to maintain or have true or real-time global
knowledge of all channel assignments in the entire
constellation. Satellites maintain channel assignment
information of satellites within their local region. The
35 present invention is superior to a global knowledge
approach because satellites never exchange channel
assignment information with satellites outside their local
region. Furthermore, the communication bandwidth required

to send channel assignment information around the network is greatly reduced. Another advantage is that the time required to propagate channel assignment information is greatly reduced. Satellites receive direct information

5   from the satellites whose channels can interfere with them, and the chain reaction effect of channel assignment is captured because the regions interlock.

In addition, the present invention is superior to a channel assignment approach based on predicted demand

10   because channel assignment is based on actual real-time demand. The uncertainties and limitations of predicted demand are avoided.

While the invention has been described in terms of specific examples and with specific preferred embodiment,

15   it is evident that many alternatives and variations will be apparent to those skilled in the art based on the description herein, and is intended to include such variations and alternatives in the claims.

As described herein, the advantages of the present

20   invention will be apparent to those of skill in the art and provide an improved methods of operating various parts of a communication system. These advantages include a dynamic assignment of communication channels in real-time based on actual demand. The tradeoff between system

25   capacity and channel interference is optimized through the use of interlocking local regions.

CLAIMS

What is claimed is:

1. A method of operating a node in a communication
system comprised of a plurality of nodes, each node
projecting antenna beams on earth's surface, said method
comprising the steps of:

establishing a local region associated with said
node, said local region comprising a set of nodes of said
plurality of nodes that are above a radio horizon of said
node;

assigning a channel to a subscriber unit, said
channel being non-interfering with channels currently
assigned by said node and by said set of nodes of said
local region, said subscriber unit being within said
antenna beams associated with said node;

notifying each node of said set of nodes of said
local region that said channel has been assigned by said
node; and

determining channels currently assigned by said set
of nodes, and wherein the assigning step assigns said
channel from a pool of channels, said pool of channels
comprising channels not currently assigned by any node of
said set of nodes.

2. A method as claimed in claim 1 wherein the
determining step includes the step of receiving a message
from at least one node of said set of nodes, said message
informing said node of channels assigned by said at least
one node, and

wherein the method further comprises the step of
storing said channels assigned by said at least one node
in a channel assignment table, and wherein the determining
step includes the step of comparing channels in said
channel assignment table with said channels not currently
assigned.

3.   A method as claimed in claim 1 wherein the
notifying step includes the step of sending a message to
each node of said set of nodes of said local region, said
message informing each node of said set of nodes of said
5   channel assigned in said assigning step.

4.   A method as claimed in claim 1 wherein:
the establishing step includes the step of defining,
by a first node of said plurality of nodes, a first local
10   region associated with said first node, said first local
region comprising a first set of nodes that are above said
radio horizon of said first node;
the assigning step includes the step of assigning, by
said first node, a first channel to said subscriber unit,
15   said first channel being non-interfering with channels
currently assigned by said first node and said first set
of nodes of said first local region, said subscriber unit
being within said antenna beams associated with said first
node;
20   the notifying step includes the step of notifying, by
said first node, each node of said first set that said
first channel has been assigned by said first node;
establishing a second local region by a second node
of said plurality of nodes, said second local region
25   including a second set of nodes that are within a radio
horizon of said second node, some nodes of said second set
being members of said first set of nodes, some member
nodes of said second set that are not members of the first
set are not within a radio horizon of some of said members
30   of the first set;
assigning a second channel to a second subscriber
unit, said second subscriber unit located within a second
antenna beam that is associated with said second node,
said channel being non-interfering with channels currently
35   assigned by said second node and nodes of said second set,
said channel being from a local pool of channels that does
not include channels assigned to nodes of said first set
that are not part of the second set; and

notifying nodes of said second set that said second channel has been assigned by said second node.

5. A method as claimed in claim 1 further comprising the step of establishing, by each node of said plurality of nodes, an associated local region that overlaps adjacent local regions.

6. A method as claimed in claim 1 wherein the establishing step is performed by each node of said plurality of nodes, and said method further comprises the step of notifying, by each node, other nodes of its associated local region whenever one node assigns a channel to a subscriber unit.

7.   A communication station comprising:

a transceiver for transmitting and receiving data to and from other communication stations that are above a radio horizon of said communication station;

5   a processor coupled to said transceiver, said processor including:

means for defining a local region associated with said communication station, said local region comprising said other communication stations; and

10   means for assigning a communication channel to a subscriber unit, said communication channel being non-interfering with communication channels currently assigned by said other communication stations of said local region, and wherein

15   said transceiver includes means for notifying each communication station of said local region that said communication channel has been assigned by said communication station, and

wherein said communication station further comprises:

20   a second transceiver coupled to said processor for producing antenna beams for communicating with said subscriber unit, wherein said subscriber unit is located within one of said antenna beams; and

a means for storing channel assignments coupled to

25   said processor,

and wherein said transceiver includes means for receiving messages from said other communication stations, said messages informing said communication station of communication channels assigned by said other

30   communication stations;

said means for storing contains a channel assignment table comprising said communication channels assigned by said other communication stations; and

said processor includes means for comparing

35   communication channels in said channel assignment table with communication channels not currently assigned by said other communication stations of said local region.
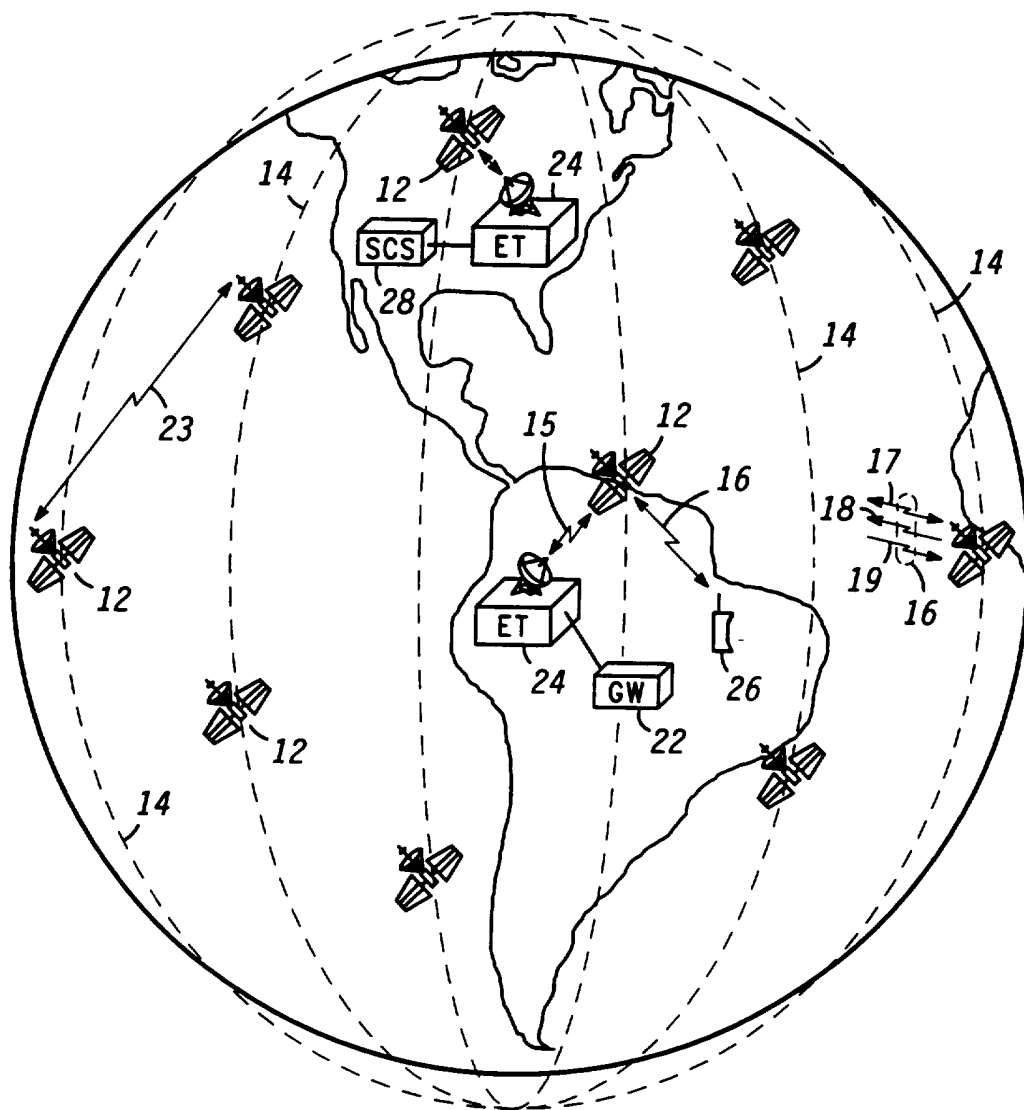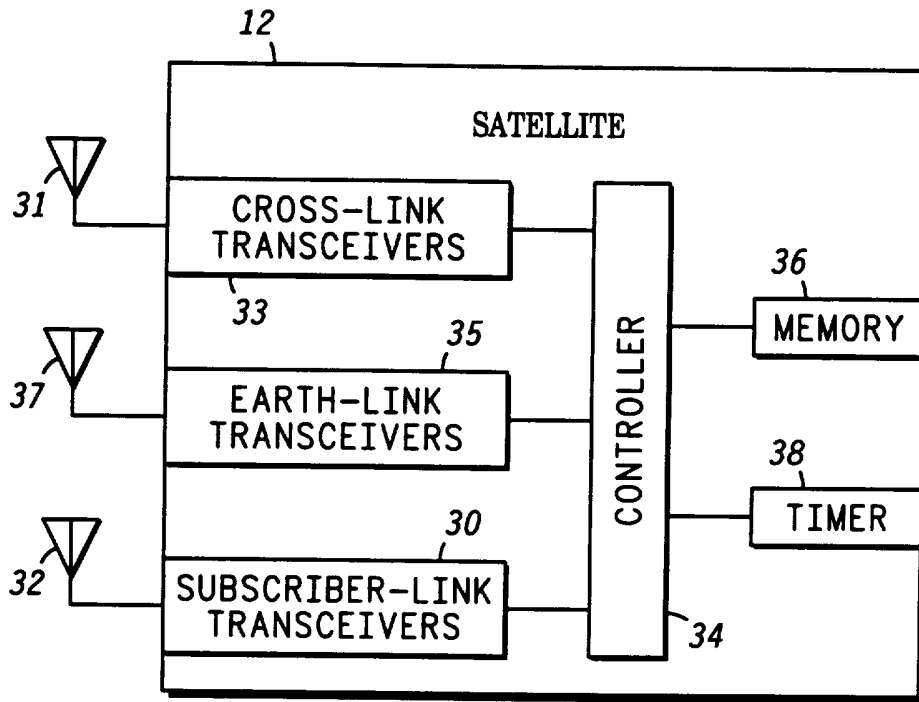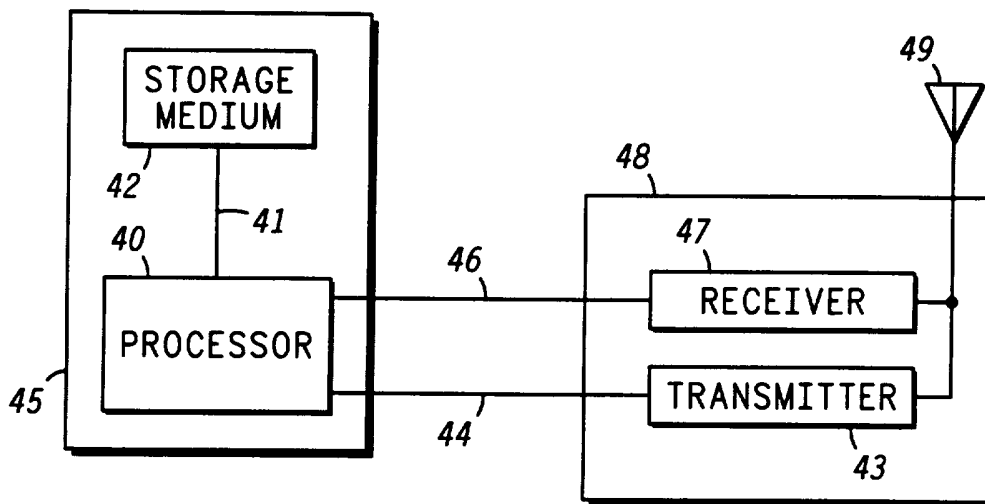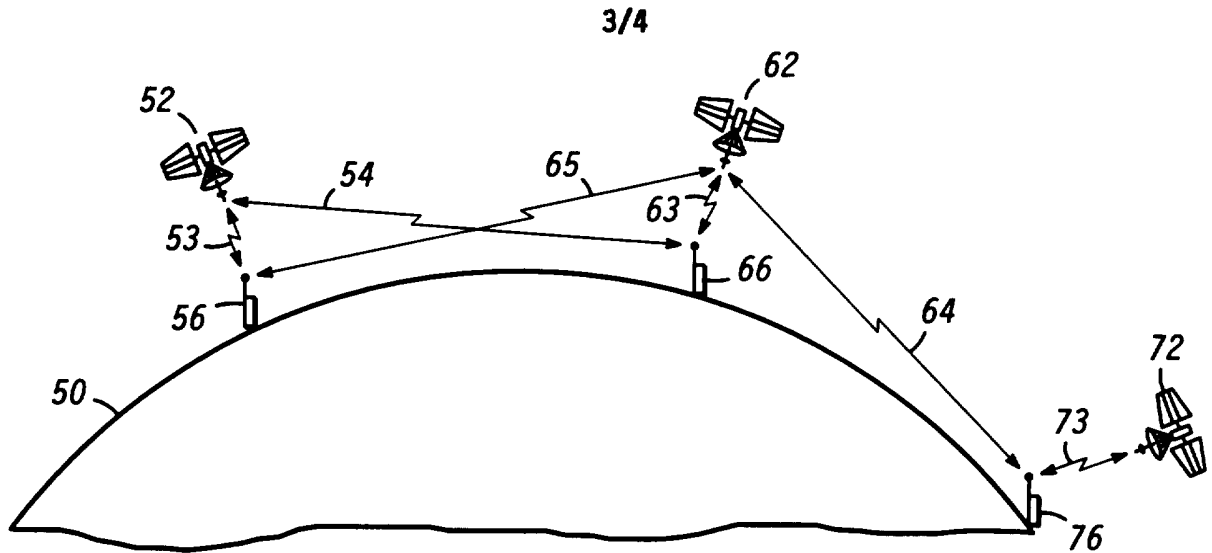
FIG. 1
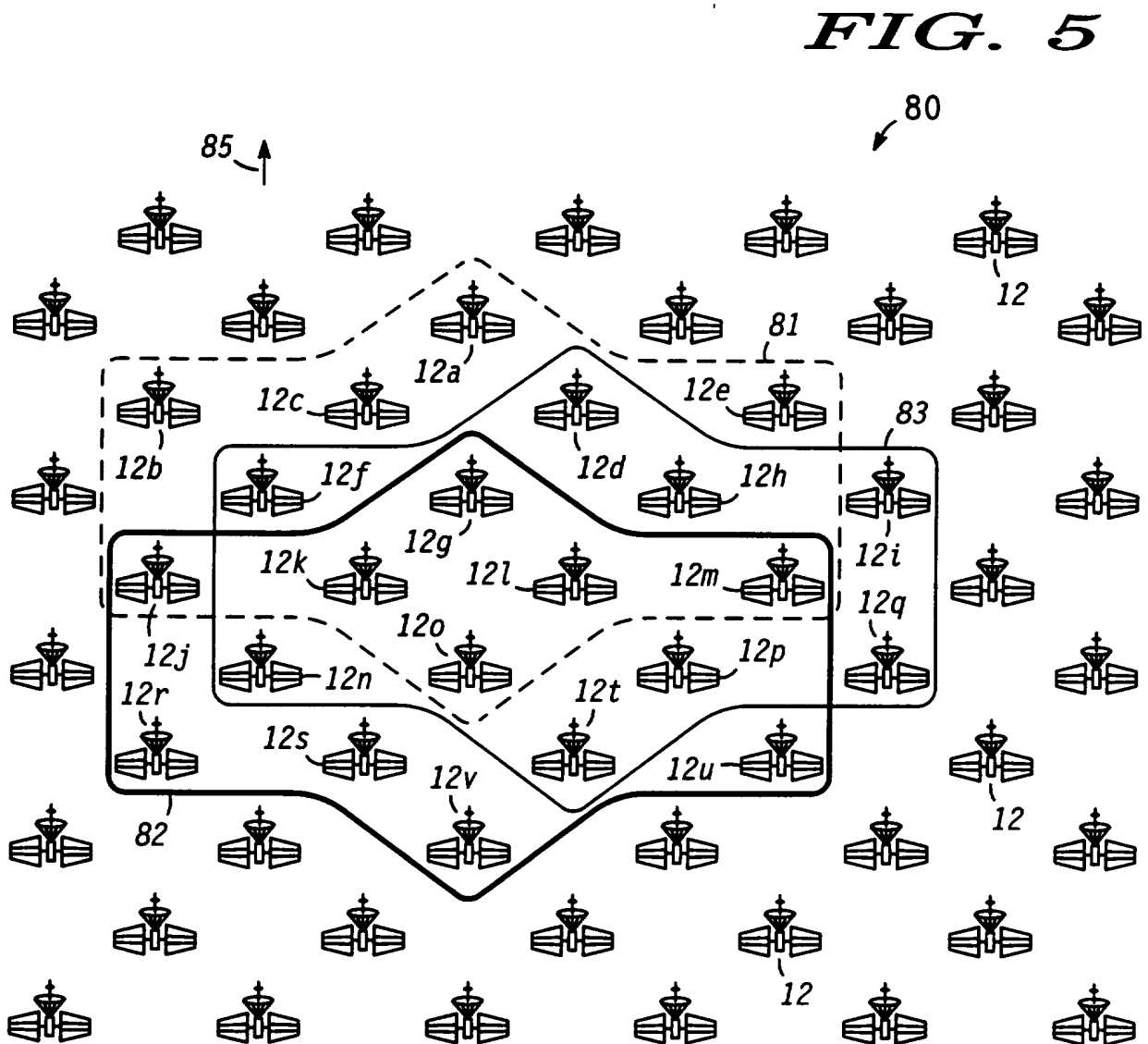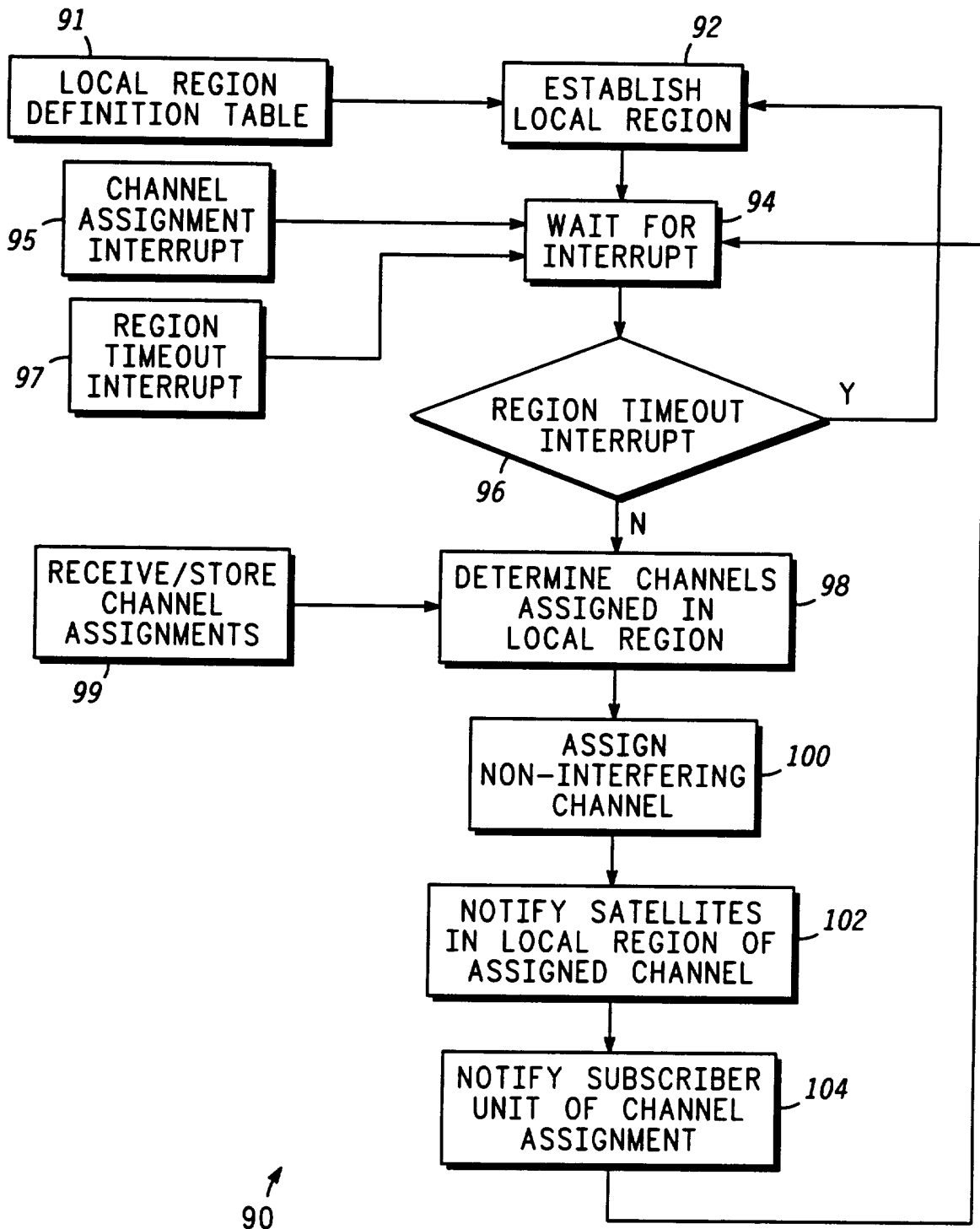
12

SATELLITE

31

CROSS-LINK
TRANSCEIVERS

33

37

EARTH-LINK
TRANSCEIVERS

35

32

SUBSCRIBER-LINK
TRANSCEIVERS

30

CONTROLLER

34

MEMORY

36

TIMER

38

FIG. 2

FIG. 3

STORAGE
MEDIUM

42

41

40

PROCESSOR

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46

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48

47

RECEIVER

TRANSMITTER

43

49

FIG. 4

FIG. 5

FIG. 6

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04B 7/185

US CL   :455/33.1, 33.4, 34.1, 34.2, 63, 12.1, 13.1

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)

U.S. : 455/33.1, 33.2, 33.4, 34.1, 34.2, 54.1, 56.1, 62, 63, 67.1, 67.3, 11.1, 12.1, 13.1; 342/354; 379/59, 60

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

NONE

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

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 5,123,112 (CHOATE) 16 June 1992, col. 3, line 6 to col. 4, line 48	1-7
A	US, A, 5,268,694 (JAN ET AL) 07 December 1993, col. 3, line 39 to col. 6, line 12, figures 1-2.	1-7
A, P	US, A, 5,394,561 (FREEBURG) 28 February 1995, col. 2, line 34 to col. 4, line 68.	1-7

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)		
"O"	document referring to an oral disclosure, use, exhibition or other means	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 OCTOBER 1995	08 DEC 1995

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