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(54) Title: WIRELESS LOCAL AREA NETWORK COMMUNICATIONS SYSTEM
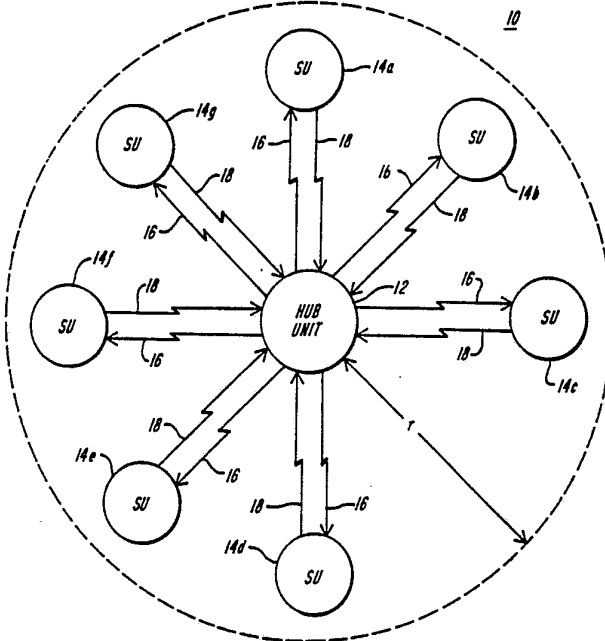
(57) Abstract

A local area network (10) including at least one hub unit (12), at least one associated station unit (14a-14g), a wireless communication link between each hub unit (12) and its associated station units (14a-14g). The communication link includes a wireless down-link channel (16) for transferring information from each hub unit (12) to its associated station units (14a-14g) and a wireless up-link channel (18) for transferring information from each station unit (14a-14g) to its associated hub unit (12). Communication is conducted in accordance with a combination time division multiplexing and contention based protocol. A synchronized common slotted time frame between each hub unit (12) and its associated station units (14a-14g) is imposed by the hub unit (12).

WIRELESS LOCAL AREA
NETWORK COMMUNICATIONS SYSTEM

Background of the Invention

This invention relates to multiple access communication systems. More particularly, it relates to multiple access wireless local area network (LAN) communication systems.

The need for wireless interconnection of computers operating over LANs has become increasingly apparent as the popularity of LAN usage in office environments has grown. Traditionally, computers and computer related devices operating as part of a LAN have been interconnected using such conventional technologies as twisted pair, coaxial cable and optical fiber cable. A primary goal of conventional systems has been to utilize these technologies to realize fast, reliable, multiple access communications over the LAN. Historically, several communication protocols and topological architectures have been combined with traditional interconnection technologies to realize this goal.

In attempting to achieve the goal of fast communication, the issue of how to make efficient usage of the chosen transmission medium was repetitively addressed by prior art systems. A common trade off encountered with respect to bus allocation is how to allocate bus usage between high duty cycle subscribers and low duty cycle subscribers

whose transmissions are characterized by a high
peak-to-average transmission rate. Such low duty
cycle subscribers are commonly referred to as
"bursty" subscribers. Three general approaches were
developed; time division multiplexing, frequency
division multiplexing and space division multiplexing.

Time Division Multiplexing (TDM) attempts to
take advantage of transmission mediums which can
support a faster communication data rates then are
required by any one user on the network.
Essentially, multiple digital communication signals
are interleaved in time over a single transmission
path. Many different types of TDM based systems. have
become well known in the art. Examples include
polling, priority request, communication path
contention, and cyclic time division systems.

In a polling system, a central controller
polls remote stations, offering each an opportunity
to utilize the communication path. In a priority
request system, remote stations request usage of the
communication path and a central controller awards
control of the path according to priority levels
assigned to each station. Contention systems
generally involve remote stations transmitting at
random times and then retransmitting in the event of
a detected collision. In a cyclic time division
implementation, devices on the network are only
permitted to transmit during a preassigned
periodically occurring time slot. Some cyclic time
division systems have fixed slot lengths and a fixed
period while others allow for these parameters to be
dynamically updated. Still others control the length

of the time slots by passing a digital code, called a token, between devices operating on the network. Only when a device possesses the token, may it transmit.

Frequency Division Multiplexing (FDM), attempts to exploit transmission mediums which can support a wider bandwidth than is necessary to accommodate the highest frequency baseband device coupled to the network. In an FDM system, each transmission signal is modulated onto a different carrier signal operating about a particular center frequency. Each unique carrier signal is referred to as a channel. One example of frequency division multiplexing is frequency shift keying (FSK). FSK systems may be designed to operate in either a full or half duplex environment. A full duplex implementation assigns separate channels for transmission and reception, thereby enabling transmission and reception to occur simultaneously. Alternatively, half duplex systems require a single channel to be time multiplexed for both transmission and reception. FSK systems generally represent a logical one by a frequency shift in a particular direction relative to the center frequency. Similarly, a logical zero may be represented by an equivalent frequency shift in the opposite direction.

Space Division Multiplexing (SDM) simply adds more signal paths which are spacially isolated from each other, thereby increasing the number of signals that can be simultaneously transmitted. As implemented in a local area network, this involves providing a separated interconnection between any two devices wishing to communicate.

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Another common issue raised in attempting to efficiently utilize a transmission medium is whether to implement a baseband or a broadband system. In the context of LANs, broadband refers to any system which transmits the digital information as an analog signal. One example is the FSK approach discussed above. Another example is phase shift keying (PSK). As the name suggests, PSK entails representing a logical one by a signal having a particular frequency and a particular phase while representing a logical zero by a signal having identical frequency but being phase shifted by a predefined amount.

The transmission path multiplexing approaches discussed above have traditionally been applied to various permutations of four topological architectures. These topologies are commonly referred to as; bus networks, loop networks, ring networks and star networks.

A bus network is one of the simplest configurations. In this type of a system the network is typically comprised of a passive transmission bus. The bus may consist of a single cable or many branches. Devices operating on such a network, commonly referred to as subscriber devices, interface directly to the bus and every device has access to transmissions from every other device. Since the bus is passive, it is the responsibility of the devices operating over the network to manage bus access. Traditionally, both frequency and time division multiplexing have been employed on such systems.

A loop network typically consists of an inbound unidirectional signal path, an outbound unidirectional signal path and a unidirectional path coupler for transferring signals from the inbound path to the outbound path at the system head-end. A loop network may also be a passive system. However, in some prior art implementations, a digital bus repeater (DBR) is employed as a path coupler. A DBR provides certain minimal formating functions and regenerates signals tending to deteriorate over long signal paths. Devices operating on a loop network typically interface to the network via an appropriate bus interface unit (BIU). As in the case of bus networks, both frequency and time division multiplexing have been utilized for efficient transmission path allocation.

A ring architecture, in its most rudimentary form, is a unidirectional closed loop signal path. Typically, devices may interface to the ring either directly or through an appropriate BIU. In some prior art implementations DBRs are inserted into the signal path periodically around the ring, and each subscriber device interfaces to the ring via a DBR. In other prior art implementation, two concentric unidirectional rings are employed. In an analogous fashion to the loop network, one ring services incoming communications signals while the other services the outgoing. Since the ring is a predominantly passive network, the devices operating over the network are responsible for efficient network allocation.

A star network typically involves having
each subscriber device connected, via a dedicated
communications path, to a central communication
controller. Traditionally, if one device on the
network wishes to send a message to another device on
the network, it transmits the message to the central
controller and the central controller, in turn,
redirects the transmission to the appropriate
destination device. In other prior art
implementations of star networks the central
controller acts as a switching unit. As such,
instead of relaying communications, upon request from
a transmitting device, it performs switching
operations to physically connect a transmitting
device to a specified receiving device. As can be
seen, the central controller relieves the subscriber
devices of responsibility for efficient network
allocation.

Many common prior art implementations have
been developed which employ contention type time
multiplexing protocols in an attempt to realize the
most advantageous usage of the above discussed
topologies. One early implementation, capable of
utilizing either a bus, loop or ring topology can be
characterized as a free-for-all system. According to
this early implementation, subscriber devices
transmitted at random and then waited a period of
time for an acknowledgment from the destination
device. If no acknowledgment was received then the
sending device retransmitted. A substantial
deficiency of this system was the number of
communication collisions caused by contending
subscriber devices.

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Subsequent prior art implementations improved on this approach by adding a carrier sensing feature. Generally referred to as carrier sense multiple access (CSMA) or listen before talk (LBT), this protocol required transmitting devices to determine whether the shared communication path was available prior to beginning a transmission. However, this protocol, nevertheless, suffered inefficiencies because collisions of simultaneously transmitted signals went undetected until the transmitting device failed to receive the expected acknowledgment from the receiving device.

The CSMA approach was later improved upon by the addition of collision detection (CSMA/CD), also known as a listen while talk protocol (LWT). According to a LWT protocol, the transmitting device monitors the bus during transmission so that a collision is detected at the earliest possible time. Considerable time savings occur by early detection if transmission distances are such that there is a long round trip delay between the transmitter and the receiver. Additional time savings occur when lengthy communications are involved and a collision occurs early on in the transmission.

Several non-contention based prior art systems have been developed which relieve subscriber devices operating on the network from having to detect collisions. One such implementation which tends to eliminate communication collisions is a cyclic TDM approach, commonly referred to as a token passing ring. As the name suggests, this network exploits a ring type architecture. In a token

passing ring system, the devices on the network
continuously pass, between themselves, a digital
code, called a token. Only when a device possesses
the token, may it transmit data over the ring. In
this way network communications are interleaved in
time. FDM may also be utilized to modulate the
baseband signals being time multiplexed over the
communication path.

Two other implementations of cyclic TDM
systems are well known in the art. They are fixed
slot allocation and dynamic slot allocation. In a
fixed slot allocation system, regularly occurring
time slots in a repetitive framed sequence are
dedicated to specific devices operating on the
network, for their transmissions. In dynamically
allocated systems, parameters such as the size of
each time slot and the number of time slots allocated
to a particular device may be varied. Since a device
only transmits during its allocated time slots,
communication collisions generally do not occur.

Although the above discussed prior art
implementations have succeeded in realizing fast,
reliable, secure communications in a multiple access
LAN environment, they nevertheless suffer from
substantial deficiencies. High on the list of
drawbacks to a hardwired system is the considerable
cost of installation resulting from having to run
cables throughout an office. Another deficiency is
the difficulty associated with relocating subscriber
devices within an office. A further drawback of
hardwired systems is the cost and difficulty
associated with moving an entire system from one

location to another. Therefore, the most recent
activity in the field of LANs has centered around the
development of wireless LANs.

There are two primary technologies being
developed to provide wireless LAN connections. One
is infrared light and the other is radio. Most
systems that propose the use of light to transmit
data over a local area networks focus on wavelengths
in the infrared part of the visible spectrum. This
choice is natural because the physical devices for
transmitting are plentiful and inexpensive.
Additionally, infrared technology is also suited to
very high data rates.

However, infrared communication systems are
mostly limited to line-of-sight links because light
cannot penetrate doors and walls. Systems which use
diffused sources and which rely on reflections off
walls and ceilings have been built, but none have
succeeded in multiple-room environments without the
use of extensive repeater networks. Additionally,
infrared tranceivers are easily interrupted by people
walking around an office.

Radio waves have long been used for voice
communication. Hand-held walkie-talkies are
essential for plant-maintenance personnel in large
office buildings. FAX and telephone communications
over cellular radio links are becoming integral to
many modern businesses. The use of radio technology
for high speed data communication over such links is
now emerging.

The primary advantage that radio has over
infrared is its ability to penetrate most solid
objects found within a building. Consequently,
objects such as wall boards, wood doors, modular
office walls, and people will not disrupt a radio
signal to the same degree as an infrared signal.
However, prior art systems have yet to completely
overcome several difficulties inherent to designing a
radio based LANs for operation in an office
environment.

One significant difficulty is effectively
dealing with multiple signal paths created by
transmission signal reflection. Other issues involve
guarding against unauthorized reception of
communication signals and interference with those
signals.

The FCC has recognized the need to use radio
transmissions for commercial in-building
communication systems and has allocated three
separate bands for low powered systems that do not
require user licensing. Specifically, these
frequency bands are 902-928 MHz, 2.4-2.5 GHz, and
5.8-5.9 GHz. The 902-928 MHz band is both fairly
narrow and crowded with such devices as store
security systems and paging systems. However, the
other two bands offer sufficient bandwidth to
transmit data at LAN megabit data rates and they are
virtually free of interference from other devices.

Another frequency band that is being used
for wireless networks is 18-19 GHz. This frequency
range does offer a great deal of bandwidth, ten 10

MHz channels. However, the use of this band requires
an FCC license on a per location basis. This
restricts the freedom a user has in installing a
wireless LAN as well as the ability to move the
system. Connection costs are significantly higher
because the cost of radio components increases along
with the frequency.

Another drawback to utilizing this band is
that it is very close to infrared and as a result,
shares many of the propagation characteristics of
light. Since signal penetration of solid objects,
such as walls is low, the effective range is small,
typically a 40 foot radius. This increases the need
to provide many repeaters to cover a typical office
environment and further increases the overall system
cost.

Accordingly, it is an object of the present
invention to provide a wireless, radio frequency,
multiple access communication system for use within
an office environment.

It is a further object to provide a
wireless, radio frequency, multiple access
communication system which is effectively immune to
information transmission problems caused by signal
reflections.

It is another object of the invention to
provide a wireless radio frequency, multiple access
communication system which accommodates both high and
low duty cycle subscribers.

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An additional object of the invention is to
provide a wireless radio frequency, multiple access
communication system which implements a carrier sense
multiple access with collision detection protocol.

Another object of the invention is to
provide a wireless system which avoids any need for
FCC licensing, thereby providing the user with
additional flexibility with respect to system
installations and subsequent system relocation.

Summary Of The Invention

The invention is directed to multiple access
communication systems. In particular, it relates to
a local area network including at least one hub unit,
one or more associated station units, and a wireless
communication link between each hub unit and its
associated station units. The wireless communication
link includes a wireless radio frequency signal path
for transferring information from each hub unit to
all of its associated station units at a first
frequency, f_1. The communication link also includes
a wireless radio frequency signal path for
transmitting information from each station unit to
its associated hub unit at a second frequency, f_2.

According to the invention, f_1 and f_2 are
frequencies at which reflections from local objects
may occur, causing a plurality of the first and
second frequency paths to exist between a particular
hub unit and an associated station unit. The
invention includes recovery elements for recovering
the transmitted information signal, by combining
signals passing over the plurality of paths.

The invention also includes synchronization
elements for establishing a common slotted time frame
for each hub unit and its associated station units
and for allocating subsets of the slots of the time
frame to each of the associated station units. A
combination slotted and contention-based
communication protocol is utilized.

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Brief Description Of The Drawings

        The foregoing and other objects of this
invention, the various features thereof, as well as
the invention itself, may be more fully understood
from the following descriptions, when read together
with the accompanying drawings in which:

        FIG. 1 shows a block diagram of a wireless
communication system in accordance with the invention;

        FIG. 2 shows a detailed block diagram of a
station unit in accordance with the system of FIG. 1;

        FIG. 3 shows a block diagram of the hub unit
of FIG. 1 acting as a central controller for a
plurality of networks, both wired and wireless;

        FIG. 4 illustrates a communication format
utilized by the up-link channel of the invention;

        FIG. 5 illustrates spread spectrum encoding;

        FIG. 6 depicts a block diagram of a
Transmitter section of a Wireless Transceiver
according to the invention;

        FIG. 7 is a detailed block diagram of
baseband and IF modules of FIG. 6;

        FIG. 8 depicts a block diagram of the
Receiver section of a Wireless Transceiver according
to the invention; and

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        FIG. 9 is a more detailed block diagram of
the baseband and IF modules of FIG. 8.

Description Of The Preferred Embodiment

BASIC SYSTEM ARCHITECTURE

FIG. 1 shows a wireless multiple access
communication network 10 according to the invention.
The system of FIG. 1 includes a Hub Unit (HU) 12 in
radio communication with a plurality of Subscriber
Units (SUs) 14a-14g. All transmissions from the HU
12 to the SUs 14a-14g are over a channel 16. That
channel operates at a frequency of 5.78 GHz in the
depicted embodiment. All transmissions from the SUs
14a-14g to the HU 12, are over an up-link channel
18. The SU to HU transmission frequency is 2.44
GHz. Both channels, 16 and 18 thus operate at
frequencies at which significant reflections occur
from local objects.

As is shown in FIG. 2, according to one
embodiment of the invention a typical SU 20 is
comprised of a data terminal 22, a wireless
transceiver 24 and a network interface 26. The data
terminal 22 may be a programmed digital computer or
computer-related device. The wireless transceiver 24
is coupled to the data terminal 22 by way of the
cable 27 and the network interface 26. The network
interface 26 is typically mounted internal to the
data terminal 22 and converts information from the
format being utilized over the wireless network to
the particular format used by the data terminal 22.
In the wireless system of FIG. 1, the wireless
tranceivers included in SUs 14a-14g transfer
information, over the wireless network 10, between
the SUs 14a-14g and the HU 22. Similarly, the HU 22
also includes a wireless transceiver operating in a
comparable fashion.

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Referring to FIG. 1, HU 12 controls all
communication occurring over the wireless network
10. It receives transmissions on the channel 18 from
the wireless tranceivers associated with particular
SUs and rebroadcasts those communications over the
channel 16 to all SUs 14a-14g on the network 10. The
HU 12 has associated with it an Effective Service
Area which defines an area of coverage 19 which may
be generally characterized by a maximum HU to SU
radial distance, r. In a preferred embodiment, the
Effective Service Area has an r of at least eighty
meters and each HU supports at least sixty-two
wireless units. In systems with more than on HU,
with each HU having an associated set of SUs, the
Effective Service Areas of multiple HUs may overlap.
However, some denegration in performance may occur
along the overlapping areas.

The HU 12 also acts as the agent for all
network management functions. One example of such a
function is collecting appropriate performance and
error statistics. Another management function
involves executing all control commands, such as
enabling and disabling specific wireless
transceivers. Although FIG. 2 depicts a SU as being
comprised of a single data terminal having a
dedicated wireless transceiver, this may not be the
case in other embodiments.

FIG. 3 depicts an alternative embodiment of
the invention wherein an HU 30 acts as the central
controller for a plurality of networks 32, 34, 36 and
38, both hardwired and wireless. As shown in FIG. 3,
each of those networks is an Ethernet local area

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network having two or more computers functioning as
terminals at there respective Ethernet nodes. Each
network 32, 34, 36 and 38 may also be considered to
be an SU in the present invention. Network 32
includes a plurality of data terminals 32a-32c
connected to an Ethernet bus 32' and an additional
network controller 38. Network 32 is in
communication with the HU 30 by way of a wired
interconnection 40. The HU 30 is also in
communication with the network manager 38 via modem
42 and a wireless transceiver 44. Network 34
includes data terminal 34a coupled to Ethernet bus
34' and communicates with the HU 30 via wireless
transceiver 34c. Likewise, network 36 comprises data
terminals 36a-36c coupled to bus 36' and communicates
with the HU 30 through wireless transceiver 36d.
Finally, network 38 includes data terminals 38a
coupled to bus 38' in communication with the HU 30
via wireless transceiver 38c.

As in the case of the system of FIG. 1, the
HU 30 receives transmissions over channel 18 from the
various wireless tranceivers and retransmits them
over channel 16 to all devices in its Effective
Service Area. It also sends this same information
over a wired connection 40 to bus 32'. Information
transmitted to the HU 30 from the bus 32' is also
broadcast to all wireless tranceivers. As can be
seen from network 36, a single wireless transceiver
may support a plurality of data terminals operating
over a hardwired network.

In the illustrated embodiment, the hardwired
network is an IEEE 802.3 (Ethernet) type system and

the wireless transceiver appears to the wired network
as an IEEE 802.3 Media Access Unit (MAU).
Alternatively, when the wired network is an IEEE
802.5 (token ring) network, the wireless transceiver
appears to the network as part of the ring wiring.

COMMUNICATIONS PROTOCOL OVERVIEW

The network communications protocol is
described below in terms of the basic architecture
depicted in FIG. 1. However, the same protocol is
readily applied to the more complex system of FIG. 3.

Referring to FIG. 1, the HU 12 transfers
information to its associated SUs 14a-14g via a
down-link radio communication channel 16 having a
frequency of 5.78 GHz. Likewise, the SUs 14a-14g
transfer information to the HU 12 over an up-link
radio communication channel 18 having a frequency of
2.44 GHz. Substantially all communications to the HU
12 are rebroadcast over the down-link 16 to all
associated SUs 14a-14g. If one SU wishes to
communicate with another SU, then the transmission is
first directed, via the up-link 18, to the HU 12.
The SU for whom the communication is intended will
receive it during the HU's 12 rebroadcasting.

Communication between the HU 12 and its SUs
14a-14g is conducted utilizing a combination
contention and time division multiple access (TDMA)
based protocol. The specific type of time division
multiplexing employed is a form of dynamic slot
allocation. Therefore, the HU 12 identifies which SU
14a-14g is transmitting from either an explicit

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identifier in the transmission or from the particular
time slot in which the transmission occurs.
Likewise, a particular SU identifies HU transmissions
intended for it by when the transmission occurs or by
an identifier in the transmission.

A traditional slotted protocol typically
involves the HU 12 establishing a common time frame
between itself and all SUs 14a-14g operating over the
network 10; dividing the common time frame into a
plurality of cyclicly repeating time slots; and
assigning one or more time slots to each SU 14a-14g.
In a typical slotted system, each SU 14a-14g is
restricted to only transmitting over the wireless
network 10 during its assigned time slots.
Additionally, if dynamic allocation is employed, the
HU 12 is able to modify such parameters as the number
of time slots assigned to a particular SU 14a-14g and
the length of such time slots. Since no two SUs
14a-14g are ever transmitting at the same time, a
plurality of SUs 14a-14g can share a common
transmission frequency without concern for signal
collisions.

Traditional slotted systems, even when
dynamic allocation is employed, suffer from
inefficiencies encountered from trying to accomodate
both bursty and high duty cycle SUs. As previously
discussed, some prior art systems have attempted to
overcome these inefficiencies by utilizing slotted
allocation over a portion of the defined time frame
to accomodate the high duty cycle users and utilizing
a contention based protocol over another portion of
the time frame to accomodate the bursty type users.

Although that approach is an improvement over
traditional slotted systems, communication over the
contention portion of the time frame can be slowed
greatly due to multiple communication collisions
between contending devices.

The system of FIG. 1 implements an
alternative variation of a dynamically allocated time
slotted system. Initially, the HU 12 imposes a
common slotted time frame. During this period the
SUs 14a-14g requiring use of the up-link channel 18,
utilize assigned time slots to broadcast Transmit
Request Codes to the HU 12. The HU 12 identifies
which SU is requesting access to the up-link 18 by
the particular time slot in which the request
arrives. The HU 12 grants access to the up-link
channel 18 by responding affirmatively to the
requesting SU. Once granted access to the channel
18, the transmitting SU has sole control until it
completes its transmission. Information is
transmitted over the network as discrete packets.
Therefore, access time can be regulated by limiting
the number and size of data packets that an SU is
allowed transmit pursuant to any single transmission
request.

A considerable advantage of this system is
that it more efficiently accomodates both high duty
cycle and bursty type users. Since assigned time
slots are primarily used for exchange of short
control type messages such as Transmit Request Codes,
they can be made very small as compared with time
slots utilized in many prior art systems. Therefore,
a time slot assigned to a particular SU occurs more

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frequently, therein increasing the likelihood of fast
access to the transmission channel. Additionally,
the packet size and quantity limitations ensure that
high duty cycle users will not load down the network
to such a degree that bursty type users are not
adequately serviced. Furthermore, since the HU 12
may dynamically change the number of packets that a
particular SU may transmit pursuant to a single
transmission request, the network can accomodate
occasional long transmissions. The HU 12 may also
assign more than one time slot to a particular SU,
causing certain high priority users to be serviced
more often. Time slot assignment is also dynamically
updatable, generally by the HU 12.

Imposing a slotted time frame during the
period when SUs 14a-14g are requesting up-link
channel 18 access substantially reduces communication
collisions between competing SUs. However,
collisions nevertheless, have the potential to occur
during the time when one SU is transmitting and
another SU wishes to request up-link channel access.
Therefore, the requesting SU must not only
synchronize itself to a preassigned time slot, but
must also ensure that the HU 12 has not previously
allocated sole control of the channel 18 to another
SU. To ensure the channel 18 has not been previously
allocated, the HU 12 imposes a listen before talk
(LBT) protocol. Accordingly, prior to broadcasting a
request, an SU 14a-14g monitors the HU down-link
channel 16, to determine that no other SU is in the
midst of transmitting. This further reduces the
chance of communication collisions.

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Regardless of the LBT collision avoidance approach, communication collisions sometimes occur as a result of the round trip communication delay between the HU 12 and the SUs 14a-14g. Therefore, the HU 12 also imposes a Listen While Talk (LWT) collision detection approach. This ensures the earliest possible detection of those collisions that do occur. Accordingly, each SU 14a-14g monitors the HU down-link channel 16 during transmission to ensure that its broadcasted message is correctly received by the HU 12. If the transmitting SU determines that its signal is not being correctly received by the HU 12 then it terminates its transmission, relinquishes control of the channel 18, and waits for its assigned time slot to occur so it can once again request control of the up-link channel 18.

COMMUNICATION PROTOCOL DETAIL DESCRIPTION

According to one embodiment of the invention, the time frame is divided into 64 time slots. Each time slot is further divided into symbols. Each time slot typically contains six symbols. The smallest sub-division of the time frame is a chip. A chip is essentially equivalent to a binary bit. Each symbol is typically comprised of 48 chips.

Typically, the network 10 of FIG. 1 transits through three states of operation. They are IDLE, BUSY and PACKET. As will be discussed in greater detail below, the network may transit from IDLE to BUSY, from BUSY to either IDLE or PACKET, and from PACKET to IDLE. Operation of the HU 12 and the SUs 14a-14g during each of these states is described below.

During the IDLE state the network is
operating in a slotted environment, and the HU 12 is
waiting for new packets to be received from its
associated SUs 14a-14g. The SUs 14a-14g are
permitted to broadcast requests to join the network
and Transmit Request Codes, as long as the requests
are synchronized to their assigned time slots.
Requests to join the network are discussed in greater
detail below with respect to system initialization.
While in the IDLE state, the HU 12 transmits an Idle
Code over the down-link channel 16 to all of the SUs
14a-14g at a particular data rate.

SUs that experience multiple communication
errors or that are attempting to join the network 10
may be in a subcategory of the IDLE state called IDLE
NO TX. In this state the SU is trying to synchronize
itself with the network and acquire the network
spread spectrum codes. This state is discussed in
detail in the system initialization section below.

FIG. 4 illustrates a communication format
utilized by the up-link channel of the invention.

The HU notifies a requesting SU that it has
been granted control of the up-link channel by
transmitting a BUSY code over the down-link channel,
timed in such a way that the SU being granted channel
control receives the BUSY code exactly at its slot
boundary. Consequently, to request control of the
up-link channel, a SU must broadcast its Transmit
Request Code (TRC) over the up-link channel 18, at
precisely the correct time so that, taking into
account all delays, the HU is able to cause the BUSY

code response to arrive at the requesting SU's slot
boundary. This requires each SU to have a first
preassigned time slot when transmissions are
appropriate and a second preassigned slot when
receptions directed to particular SU's should be
expected. As can be seen, the reception time slots
are delayed in time from the transmission time slots
by an amount substantially equal to the round trip
delay between the HU and the requesting SU.

The TRC is typically five symbols long. The
first symbol 402a provides the differential phase
shift keying (DPSK) reference for the HU receiver.
The following four symbols 402b comprise the actual
TRC. After the code symbols 402b, there is a one
symbol guard band 402c which ensures that the TRC
402b does not overlap into the next preassigned
slot. The four symbol length of the TRC allows the
HU to make an initial determination that this request
is not a false alarm. Following the TRC 402, the
requesting SU broadcasts a stream of fifteen ZERO
symbols to the HU 12. The first fourteen of these
symbols are known as a Collison Window 404 because
collisions may occur with TRCs from other SUs.
Collisions result from other SUs not knowing that a
particular SU is requesting access to the network
until the HU rebroadcasts the request. Thus, the
length of the collision window 404 is determined by
the round trip communication delay. If at any time
during the collision window the requesting SU
receives any transmission except a BUSY Code, it
assumes another SU has control of the channel and
terminates its transmission. The fifteenth symbol
406 is not subject to collision. The HU 12 causes

the network 10 to transit into the BUSY state
following detection of a TRC from any of its
associated SUs 14a-14g.

    If the TRC is approved by the HU 12, the HU
12 transmits a sequence of BUSY Codes for
twenty-eight consecutive symbols over the down-link
channel 16, causing all SUs 14a-14g to transit into
the BUSY state and indicating that no further
transmission requests will be entertained. The HU 12
causes the first BUSY code to occur at the slot
boundary for the requesting SU. The requesting SU
14a interprets a BUSY code, so received, as
confirmation that it has been granted control of the
up-link channel 18. This occurs at approximately the
end of the collision window 404.

    Following transition into the BUSY state,
the requesting SU 14a transmits a two symbol UPTYPE
code 408 which specifies whether it is about to
transmit a regular packet, a supervisory packet, a
transmitter test packet (TTP), or a regular packet
with buffer overflow warning. The SU 14a then
transmits a ten symbol Start-Of-Packet (SOP) Code
410. The ten symbol SOP length results from the
delay time required by Trellis encoding utilized by
the system. However, this delay time is not wasted.

    According to the invention, the HU uses the
known SOP symbols to once again confirm that a false
alarm has not occurred. Without this confirmation,
the HU would have to wait for and End-Of-Packet (EOP)
symbol to detect a false alarm. The HU 12 detects a
false alarm by performing signal quality

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measurements. If the signal quality does not meet a
predetermined threshold or if the HU 12 does not
receive the SOP code within a predetermined time, the
HU 12 declares a False Alarm, broadcasts a DOWNTYPE
code informing the SUs of the False Alarm and
transits back to the IDLE state. Any time the HU 12
causes the network 10 to transit back into the IDLE
state, it broadcasts a Information Supervisory Packet
(ISP) which includes information directing which of
its associated SUs 14a-14g is up first in the
slotting sequence. The HU 12 may assign any of the
SUs 14a-14g to be up next in the sequence, regardless
of which SU was previously being serviced. Early
false alarm detection increases network throughput by
terminating spurious communications quickly.
Moreover, having the second false alarm detection
allows the TRC to be fewer symbols than would be
necessary if false alarms were required to be
completely eliminated during the first test. Since
the required length of the TRC directly impacts the
length of the time slots, a short TRC allows for
implementation of short time slots. Short time slots
further increase network throughput because each SU
can be served more quickly. The HU further utilizes
the SOP symbols to perform signal quality
measurements used to select which of the three HU
modems (e.g., early, late, or on time) will be
utilized to receive the data portion of the
transmission.

If the signal quality level is sufficient,
then the HU 12: (1) selects a modem having the best
quality signal to receive the subsequently
transmitted symbols; (2) transmits over the down-link

channel 16 a DOWNTYPE Code announcing to the SUs
14a-14g which HU modem is to be used; (3)
rebroadcasts the Start-Of-Packet Symbols over the
down-link channel 16; (4) enables a trellis encoder
to operate during rebroadcast of the symbols
subsequently received from the transmitting SU 14a;
and (5) causes the network to transit into the PACKET
state.

During the PACKET state, the data packet 412
is broadcast from the transmitting SU 14a over the
up-link channel 18 to the HU 12. The data packet 412
is transmitted in a trellis encoded format. There is
a three symbol processing delay between reception at
the HU 12 over the up-link channel 18 and rebroadcast
by the HU 12 over the down-link channel 16. The
transmitting SU 14a includes a thirty-two symbol
check sum (CRC) 414 and a nine symbol End-Of-Packet
Code at the end of a transmission. The CRC 414 and
the End-Of-Packet Code 416 are echoed over the
down-link 16, followed by a 10 symbol Tail which
enables Trellis Decoders at the SUs 14a-14g to
complete the decoding of the data transmitted by the
HU 12 over the down-link 16.

Following rebroadcast of the packet, as
originated by the transmitting SU 14a, including the
Tail, the HU 12 disables its Trellis Encoder and
broadcasts an additional HU Message to all of its
associated SUs 14a-14g. The additional information
appended by the HU 12 is twelve symbols long and
includes five fields. Those fields are: (a) an
indication whether the transmitting station should
increase its power prior to its next transmission;

(b) an indication whether the transmitting SU's
transmission delay should remain as it is or be
increased or decreased; (c) an indication whether a
reception error was detected by he HU; (d) an
indication whether a strong interference is present
in the up-link to the HU; and (e) the index of the
first slot to be serviced following the end of the
transmission.

In the PACKET state all of the SUs 14a-14g,
including the transmitting SU 14a, receive the
rebroadcast packets from the HU 12, detect the
End-Of-Packet Code, check the CRC, decode the HU
Message and apply whatever is implied by that
message. If it is not a transmitting SU and the CRC
is good, the data filed within the packet is
transferred to the SU's processors. Upon completion
of the HU Message, the HU 12 causes the network to
transit back into the IDLE state.

TRANSMISSION FORMAT

Discussed above is the communication
protocol by which the HU 12 and its associated
station units communicate 14a-14b. As was pointed
out in the background section, there are a variety of
electrical implementations, both baseband and
broadband, for such a protocol. A system according
to a preferred embodiment utilizes a combination of
direct sequence spread spectrum (DSSS) along with
differential multiphase shift keying (MPSK) and
Trellis Code Modulation (TCM).

DSSS is a form of Code division multiplexing

(CDM), developed by the US military in the 1950's to provide reliable and secure voice communications in the field. DSSS involves spreading the power contained in a baseband signal over a broadband in a psuedo-random manner during transmission and retrieving the narrow brand signal during reception. It accomplishes this by individually coding each bit of a digital communication signal. Spread spectrum techniques are well known for their immunity to multipath fading environments, for their resistance to interference and for their natural security features.

In a multipath environment echoes of the transmitted signal are created due to reflections from various objects. These echoes are essentially replicas of the transmitted signal only delayed in time and subjected to an attenuation and a phase rotation. Each path is specified by a particular delay, attenuation and phase shift. All three parameters are independent from each other and vary in a substantially random manner. The signal delay may be expressed in terms of the delay between adjacent paths or the delay span encompassed by significant paths ("delay spread"). In an office environment, adjacent paths are typically separated in time by a few nanoseconds, while a typical delay spread is on the order of a few hundred nanoseconds.

A DSSS receiver, of the type employed in the invention, is synchronized to multiply an incoming spread spectrum signal, having a selected delay, by a despreading code. In this way, the narrow band signal is recovered. Synchronization of the receiver

is such that multiplication of incoming signals,
having delays other than the selected one, yields
substantially insignificant results as compared to
multiplication involving the signal having the
selected delay. Therefore, DSSS acts to reject
almost completely, all the channel delays which do
not match the selected delay. By repeating the
despreading process for several channel delays, the
receiver combines signals arriving at a plurality of
different time delays. A receiver which combines a
number of differently delayed signals is known as a
RAKE receiver.

        FIG. 5 depicts a simplified example of
DSSS. As can be seen, the baseband message bits
50a-50c are multiplied by digital chip pattern
52a-52d. This results in each message bit being
spread into a four bit code 54a-54c of sub-bits
56a-56r called chips. Spread spectrum code 54a
corresponds to baseband data bit 50a. Likewise, code
54b and 54c correspond to data bits 50b and 50c
respectively. In that example the signal 54 has a
bandwidth which is four times the bandwith of the
original message signal 50. Additionally, the power
contained in the original signal 50 is spread over
the extended bandwidth of the spread spectrum signal
54. Typically, the chip pattern 52 is a relatively
long psuedo-random code. Therefore, a receiver which
does not possess the psuedo-random code will not be
able to coherently combine the signal power contained
in each chip 56a-56r to reconstruct the original
message bits 50a-50c.

As is well known in the art, MPSK involves
representing binary codes by incremental shifts in
the phase of a carrier signal. In one preferred
embodiment, sixteen phases (0 - 337.5 degrees in 22.5
degree steps) are utilized to represent all possible
combinations of a four bit binary code. The
utilization of multiphase shifting improves the
throughput of the system over a standard dual PSK
system. Since it is easier for a receiver to detect
the presence or absence of a change of phase than it
is to determine the phase itself, a differential
implementation is utilized.

DPSK fits well into the indoor multipath
environment. The reason for this is that the
dynamics of an indoor multipath channel is such that
changes in response are relatively slow and may be
regarded as practically zero, from one transmitted
symbol to the next. Consequently, DPSK, which is
based on the difference in phase between adjacent
symbols is not affected by channel variations.

DPSK is also a natural match with the RAKE
processing. If K delays are processed, each of them
has an independent phase and amplitude. However, the
differential phase of each signal, nevertheless, is
representative of the transmitted phase. The
differential phase is generated by complex
multiplication of the current symbol phase by the
conjugate of the previous symbol phase. According to
the invention, a weighted average of the differential
phase vectors of each of the K delayed signals is
taken to determine a resultant vector having a
particular phase. Each signal is weighted by the

product of the amplitudes of its two adjacent delayed
signals. Through this averaging process, the signal
to noise ratio is improved.

The invention also employs Trellis
Modulation Encoding. Trellis encoding is well known
in the art. It has the advantage of having minimal
affects on the original data bandwidth while
achieving a reasonable coding gain. The coding gain
is the improvement in the signal to noise ratio. The
coding gain achieved in an embodiment of the present
invention is approximately 3dB by utilizing a four
state Trellis code.

HARDWARE DESCRIPTION

The primary components of the invention are
the Hub Unit (HU) and the Subscriber Units (SUs). As
previously discussed with respect to FIG. 2, the SU
may be further comprised of data terminal, a wireless
transceiver and a network interface. As depicted in
FIG. 3, the data terminal may be any computer or
computer related device. Moreover, an SU may include
a single data terminal or an entire network,
interfaced to the HU through one or more wireless
tranceivers. The network interfaces typically mount
internal to the data terminal and are the wired
communication interface over which information is
transferred between the wireless transceiver and the
data terminal.

Wireless tranceivers are included in both
SUs and HUs and are essentially the interpreter
between either an SU or an HU and the network. In

the case of transmissions, the wireless transceiver
receives information from the SU over the network
interface, according to the particular protocol the
SU is operating under, such as IEEE 802.3 or IEEE
802.5. The wireless transceiver then reformats the
information according to the wireless network
protocol, and transmits it over network. In the case
of SU receptions, the wireless transceiver receives
the transmission over the network, reformats it
according to the SUs particular protocol and
transmits the information, via the network interface,
to the particular SU. In the case of HU reception,
reformatting may only be necessary if the HU is also
in wired communications with another network as
depicted in FIG. 3.

Employing a down-link 16 according to the
embodiments of FIGS. 1 and 3 requires the following
synchronization processes: (1) spreading sequence
acquisition; (2) spreading sequence delay tracking;
(3) carrier frequency synchronization or compensation.

The goal of sequence delay acquisition is to
locate the RAKE "window" (the range of continuous
sequence delays to be processed) in such a way that
the power of the channel paths falling within this
window is maximized. According to the invention,
different delays are scanned by a moving digital
correlator. At a given time interval an acquisition
module compares the power measured in the current
RAKE window with the power measured within an
alternative window. The power of the alternative
window is measured by the moving correlator, while
the current window's power is measured by the K

correlators used for the RAKE demodulation. The
search for the better window is of the type "double
dwell" where, in the first dwell a short comparison
is performed the result of which, if indicating a
suspected better window, causes the longer second
dwell to occur. A measurement of a better window at
both dwells causes the RAKE window location to change
to that of the alternative one. This type of change
may result in a very short burst of symbol errors due
to the discontinuity of the respective delays' phases
prior to the differential demodulation. Therefore,
according to the invention, sequence delay
acquisition does not occur during packet reception
mode. Instead, it takes place during IDLE mode.

The goal of the delay tracking is to track
the transmitter's chip clock as well as changes in
the channel response. Local optimization of the RAKE
window location occurs as a result. To achieve
location optimization, the edges of the current
window are examined. The K delays processed by the
RAKE demodulator are designated by the indices 0 to
K-1. The two delays adjacent to the window have the
indices -1 and K. If the window spanning from -1 to
K-2 has more power than the 0 to K-1 window then the
window is shifted to the "left". If the 1 to K
window contains more power then the window is shifted
to the "right". Whether to institute a shift and in
which direction is determined by a power comparison
of the "right" window with the "left window." If the
power comparison applied at a relatively high rate
(relative to the channel time constant which is on
the order of 10ms), it results in an average window

location which is close to the locally optimal one.
Any chip clock frequency offset between transmitter
and receiver will generate a phase drift which is
tracked by applying the power comparison algorithm,
assuming the frequency offset is small, as it is when
considering practical values. If for some reason,
the multipath profile (its response described in time
domain as reflected to the receiver) changes locally
this mechanism is also able to track it. Drastic
changes are detected and adjusted for by the sequence
delay acquisition mechanism.

        Two modes can be defined for the tracking
process, "digital" and "analog." In the digital
mode, the receiver's chip clock is just a local,
crystal derived clock which does not track the
received signal. The tracking is performed by
applying the "right" and "left" energy comparisons
previously discussed and simply jumping the window
location by one chip according to that comparison.
The "right" and "left" energies are measured over
many symbols. However, an inherent location jitter
of ±1 chip occurs as a result of this technique.

        According to the analog technique, the
"right" and "left" energies are accumulated over a
much shorter period, and their comparison is not
applied directly to the window location. Instead, it
is used to drive a type of a Phase Lock Loop (PLL)
called a Delay Lock Loop (DLL). Basically, the
right/left comparison plays the role of the phase
detector, while the loop filter and VCO are as in a
standard PLL. The PLL bandwith is sufficiently

narrow to effectively filter out the jitter and
results in the average location window being very
close to the locally optimal one.

A drawback of the analog mode is its
inability to acquire and lock on the incoming chip
rate if significantly different from the VCO initial
frequency. The problem stems from the SUs using the
same chip clock for both its up-link transmitter and
its down-link receiver. This is done because the HU
uses the same clock for both up-link and down-link,
hence when the SU receiver synchronizes itself to the
HU clock, its transmitter is automatically
synchronized to the appropriate clock. A voltage
controlled crystal oscillator (VCXO), being
inherently more stable, solves this problem.
However, the use of a VCXO is much more expensive
than a simple VCO.

Regardless of the mode of window adjustment,
the impact of a window shift in the receiver is
minimized by executing the shift on a symbol boundary
(transition between adjacent symbols). By swapping
the correlator's indices between the symbols the
differential vector generation is still correct at
that transition. The effect of that shift executed
during packet transmission will be an error in the
Hub's receiver which is not aware of that change and
cannot adjust itself. Disabling that shift during
transmission is possible, however it is conditioned
on the requirement that the offset between the HU and
the SU chip clocks is small enough such that during
the longest allowed packet, the drift between them
should be maintained below some level (one chip is a
reasonable threshold).

According to this invention, a mix of the
digital and analog modes is utilized. During the
initialization stage, defined as the period before
receiving packets or other expected transmission, the
digital mode is used. Later, after the acquisition
and tracking have been proved to be valid by the
detection of correct transmissions, a switch to the
analog mode occurs.

During this initialization stage a
transmission, under this invention, is not allowed
(the up-link based on the validation of the
down-link), therefore the problem of window location
shifts does not exist. The SU receive clock is
generated by a PLL consisting of a VCO (not VCXO). a
divider by N, a phase-frequency detector, loop-filter
and a crystal oscillator at the frequency chip
rate/N. This is a standard PLL locked on a
relatively cheap low-frequency oscillator and
capable, due to the phase-frequency detector, to
acquire the approximate chip rate frequency even
though the VCO initial frequency may offset. Once
acquisition has been achieved, the digital tracking
mechanism starts adjusting the window location to
achieve, within one chip, the locally optimal
location and to digitally track phase drift due to
frequency offset.

In switching to the analog mode the
right/left comparison stops being averaged and
applied to the digital window location. Instead the
comparison outcome starts being applied as the
replacement of the phase-frequency detector in the
PLL configuration. This instantaneous switch enable

the DLL to start operating with a VCO at almost the
correct frequency and therefore, no frequency
acquisition is required and the DLL can function
properly as long as there is a signal to track.
Thus, the need for an expensive VCXO is eliminated.

The object of carrier frequency
synchronization is to compensate for any carrier
frequency offset between the transmitter and the
receiver. This is a typical problem in a system
according to the present invention wherein a large
number of phases M are employed, the carrier
frequency is very high and not very expensive
crystals are used, and the symbol period is not very
short. The requirement is basically that the
differential phase error due to frequency offset
which is $2o(\Delta f \bullet T_{sym})$ where Δf is the frequency
offset and T_{sym} is the symbol period, must be much
smaller than the transmitted phase resolution $2o/M$.
This requirement may not meet under worst case
conditions, there the invention provides for
compensation.

According to the invention, the average
post-demodulation differential phase error is
estimated. This differential phase error, if
averaged long enough, becomes very close
(theoretically equal) to $2\pi(\Delta f \bullet T_{sym})$ and can be
subtracted from the demodulated differential phases
to obtain the actual output differential phase of the
demodulator. The frequency offset changes mainly
with temperature and aging and is a very slow
process. Therefore, very long averaging of the phase
error can be accomplished to achieve a high accuracy.

A feature of the invention is that the Hub
conveys its control symbols, which determine the
state of the protocol, by using the differential
phases of 180° and 0° as logical '1' and '0', while
no other phase is used unless it is during a packet.
In addition, a minimum number of such symbols is
guaranteed between packets. A station synchronized
on the protocol knows to anticipate when these
characters should be received. The phase averager
utilizes these known characters to perform its error
correcting averaging.

FIG. 6 depicts a block diagram of the
transmitter section 130 of a wireless transceiver
according to the invention. Wired communication bus
131 may be an internal communication bus, as in the
case where the SU comprises a single data terminal or
where the wireless transceiver is operating in an
HU. Alternatively, it may be a hardwired network
bus, as in the case where the SU is a complete
network. Transmitter 130 is in communication with
bus 131 via wired interconnection 134 and network
interface 132. Digital communications, intended for
wireless transmission are passed via interconnection
134 to interface controller 136. The Interface
Controller 136 stores those digital signals in ram
buffer 140. The transmitter protocol engine 142
receives the digital signals from ram buffer 140 and
controls reformatting those signals according to the
protocol requirements of the wireless network.
According to the invention, interface 136 may access
ram 140, via I/O port 140b, at a different data rate
than the protocol engine 142 accesses ram 140 via I/O
port 140a. Dual port memory controller 138 controls
this process.

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The protocol engine 142 performs several
formatting functions. One formatting function it
performs is to encode the differential multiphase
modulation information. It accomplishes this by
encoding sixteen possible phases as four binary
bits. Additionally, the protocol engine utilizes a
forty-eight bit spread spectrum chip sequence to
further encode the digital signals. The protocol
engine 142 then passes the encoded digital signals to
the modem 148, via transmission path 144. Protocol
engine 142 also provides modem 148 with various
control and timing signals 146. The modem 148 passes
the digital data to the Intermediate Frequency (IF)
module 152 via transmission path 150. The IF module
152 latches the digital signals passed from the modem
148 and then performs an analog to digital conversion
on those signals. The IF module 152 then modulates
the analog baseband signal onto a transmitter IF
carrier at 360 MHz, according to control signals 154
provided from the protocol engine 142. The modulated
signal is then passed to radio transmitter
upconverter module 158, via transmission path 156.
At transmitter module 158 the information signal is
further modulated up to a 2.440 GHz carrier frequency
in the case of an SU transmisson and a 5.780 GHz
carrier frequency in the case of an HU transmission
and transmitted over the wireless network via antenna
160.

FIG. 7 provides a more detailed block
diagram of the IF module 152. As can be seen from
FIG. 7, the IF module 152 may be divided into a
baseband section 166 and an IF section 168. The
baseband portion 166 is comprised of the input data

latch and decoder 172, and the dual digital to analog
converters 180 and 182. The elements of the IF part
168 are the quadrature output, phase-locked local
oscillator 184, the in-phase and quadrature mixers
186 and 188 respectively, the summer 190, the
amplifier 192, external filter chain 194, the filter
buffer amplifier 196, the programmable gain control
198, the output switch 200, and divider circuitry 202.

This module processes the digital signals
170a-170d containing the spread spectrum and phase
modulation encoding which is passed on by the
protocol engine. The input data is first latched by
the input data latch and decoder 172 to synchronize
it with the transmitter clock 174 and to eliminate
potential data jitter. The four bits 170a-170d,
representing each of the possible sixteen phases
needed, are then decoded into two digital words
176a-176d and 178a-178d. Digital words 176 and 178
are then converted into analog signals at analog to
digital converters 180 and 182 respectively. The two
analog signals are then passed to the dual quadrature
fed mixer modules 186 and 188. Mixers 186 and 188
modulate the baseband data signals onto the
transmitter IF carrier at 360 MHz. Mixers 186 and
188 are matched to preserve the output phase
accuracy. The matched outputs of the mixers 186 and
188 are then summed in phase in summer 190. The
output of summer 190 is then buffered through driver
amplifier 192 and filtered through band pass filter
194. The output from bandpass filter 194 is also
buffered through amplifier 196 to buffer the
impedance of filter 194.

        The quadrature mixers 186 and 188 are fed
from a local oscillator 184 at 360 MHz whose output
is split into two signals 184a and 184b that are
separated in phase by 90 degrees. The oscillator 184
is phase-locked to an external reference signal 204
at either 5.625 MHz or 1.0 MHz depending on whether
the wireless transceiver is being used for a SU or a
HU. Likewise, the divider ratio is also selectable
at either 64 or 360 by control signal 206.

        The next stage in the transmitter IF module
152 is a programmable gain stage 198, controlled by a
four bit binary control signal 208. This stage
provides a monotonic attenuation range of 0-75 dB in
5 dB increments. The minimum value of the maximum
attenuation should be 40 dB.

        The final stage in the primary signal path
in module 152 is the on/off switch 200. When the SU
is not transmitting, switch 200 provides a mechanism
by which transmitter 130 may be turned off. Switch
200 has a minimum off state isolation of 30 dB and an
off to on delay of less than 100 ns and is controlled
by digital input 210.

        The IF module 152 also contains a divider
202. Divider 202 is used in phase-locked loops for
external microwave circuits. It consists of a
divider 212 which divides a 21.875 MHz input signal
214 by 175, a phase-frequency detector 216 which is
fed with an external reference signal 218 at 1 MHz
which is internally divided by eight in divider 220,
and a loop amplifier 222 that has external elements
224 which determine the loop parameters.

FIG. 8 is a block diagram of the receiver
portion 300 of a wireless transceiver according to
the invention. The incomming communication signal is
received at antenna 302. Where the transmission is
being received by a SU, the received signal is at a
frequency of 2.440 GHz. However, if the signal is
being received at a HU, the received signal is at a
frequency of 5.780 GHz. The signal is immediately
passed to Radio Receiver Down Converter 304 which
demodulates the signal down to an intermediate
frequency of 180 MHz. Down Converter 304 passes the
converted signal to Receiver IF Module 308 via
transmission path 306. The IF Module 308 then,
further demodulates the received signal and converts
it to a baseband digital representation. The IF
Module 308 performs its functions according to
control signals 314 provided by the Protocol Engine
320. The converted baseband digital signals are
transmitted from the IF Module 308 to the Modem 312.
The Modem 312 passes the digital signals on to the
Protocol Engine 320 via transmission path 318. The
Protocol Engine 320 strips out the multiphase
modulation information and the spread spectrum
encoding, formats the information according to the
requirements of the particular SU or HU and stores
the baseband digital information in the ram buffer
322 via port 322b. The Interface Controller 324
reads the formatted information from the RAM buffer
322 via port 322a and passes it to the wired bus 326
via the wired interconnection 328 and the network
interface 330. The wired bus 326 may be an internal
data bus as in the case where the SU is comprised of
a single data terminal or where the information is
being received at an HU. Alternatively, it may be a

hardwired network, as in the case where the SU is
comprised of an entire network. The Protocol Engine
320 and the Interface Controller 324 may access the
ram buffer 322 at two different data rates. Memory
Controller 330 coordinates this memory access.

        FIG. 9 is a more detailed block diagram of
the Receiver IF Module 300 of FIG. 8. The purpose of
the Receiver IF Module 300 is to condition the input
phase modulated signal and to convert this signal
from a polar, IF representation to a Cartesian,
baseband digital representation. The resulting
digital signals are then passed to the Modem 312 for
further processing.

        There are two functional subdivisions to
this module, an IF part 350 and a baseband part 352.
The elements of the IF part are an input amplifier
354, a programmable gain control 356, a limiting
amplifier 358, a bandpass filter 360, an I-Q down
converter mixer set 362 and 364 and a quadrature
output phase-locked local oscillator 366. The
elements of the baseband part 352 are video buffer
amplifiers 368 and 370, low-pass filters 372 and 374,
video driver amplifiers 376 and 378, a clock
generation module 380 and analog to digital
converters 382 and 384.

        The IF Module 300 receives, as its input
353, a spread spectrum, differentially encoded phase
modulated signal centered at 180 MHz with an
effective noise bandwidth of approximately 70 MHz.
The input signal to the module 352 ranges from -63
dBm to approximately -7 dBm. The signal is amplified

in a low-noise input amplifier 354 and then the
signal level is set by a programmable gain stage
356. The programmable gain stage 356 is controlled
by inputs 357 from the Protocol Engine 320 depicted
in FIG. 8. The programmable gain stage 356 acts to
compensate for unit-to-unit and temperature
variations in gain in both this module and the
preceding stages. The approximate range of the gain
control is about 16 dB. Approximately 8 dB is
allocated for prior stages and 8 dB is allocated for
module 352.

The signal is then passed to a limiting
amplifier 358 to remove any amplitude modulation
present to improve the systems dynamic range. It
also limits the magnitude of the baseband signals
applied to the inputs of the analog to digital
converters 380 and 382. After the limiter the signal
is further filtered through bandpass filter 360 and
then passed to the mixer module divider 359.

At the divider 359, the signal is split into
an in-phase channel 359a and a quadrature channel
359b for mixing down to baseband. The mixers 362 and
364 are driven by a local oscillator 366 whose
outputs 366a and 366b are 90 degrees offset from one
another. The local oscillator is a VCO at the IF
frequency and is phase-locked to an external, 1 MHz
reference signal 365 derived from a crystal
oscillator at 16 MHz.

Following conversion to baseband, the
in-phase and quadrature signals are passed to video
amplifiers 372 and 374 respectively. Amplifiers 372

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and 374 server to buffer the mixers 364 and 362 from
the impedances of the filters 372 and 374 and to
provide sufficient signal drive into those filters.
Once passed through lowpass filters 372 and 374, the
signals are buffered through amplifiers 376 and 378
and then fed into analog to digital converters 382
and 384. Analog to digital converters 382 and 384
sample the baseband signals according to clock
signals 380a and 380b generated by clocking circuit
380 and convert them to digital data. The sampling
frequency of the analog to digital converters 382 and
384 is controlled by input 386 to clock circuit 380.
The digital signals 382a and 382b are then passed to
the modem 312 of FIG. 8 for further processing.

        As was previously discussed, one embodiment
of the invention typically operates in an office
environment. In such an environment, there are many
objects such as walls, file cabinets and desks which
may act to deflect transmitted signals. This
deflection may result in creating multiple signal
paths by which a given transmission reaches its
destination. Such a multiple path channel is
characterized by each path having a different time
delay, amplitude and phase. Since the different
paths may have random independent phases, the
received combined amplitude could vary by
considerable amount and may sometimes be below the
required minimum signal level. As also noted above,
a direct sequence spread spectrum (DSSS) approach
improves on the multipath problem combining the
signals received from the different signal paths.

SYSTEM INITIALIZATION

During system initialization the HU performs
various functions. These functions are divided into
two categories: HU initialization and SU
initialization. The SU initialization functions
include allowing SUs to establish membership in the
network, and setting SU to HU transmission signal
power level and time delay parameters. The HU
initialization includes selecting the spread spectrum
code to be used, setting the HU receiver gain, and
setting the HU to SU transmission signal power
level. These initialization functions are described
below.

A particular SU is considered a member of
the wireless network when its associated wireless
terminal possesses the correct network spread
spectrum-code and has been assigned a free time slot
number. Only when the wireless terminal has both of
those parameters may its associated SU communicate
with the HU. If it has both of these parameters and
it wishes to become active on the network then it
sends a message, during its allocated time slot, to
the HU that it is active. The HU then acknowledges
activation on the network through transmission of an
identification supervisory packet (ISP). An ISP
typically consists of five fields: configuration
serial number, spread spectrum code set number,
number of configured SUs, number of active SUs and a
list of identification addresses of all configured
stations.

In a preferred embodiment, any one of a
plurality of network spread spectrum codes may be
utilized with respect to a particular HU.
Additionally, different HUs will employ different
network codes to minimize internetwork interference.
Each wireless terminal has the potential network
codes stored in an internal ROM, along with the
network configuration serial number so it can
identify the correct HU. If the wireless terminal
does not know which of the possible codes to use,
then it shifts into IDLE NO TX state and monitors HU
transmissions over the down-link channel until it
determines that code. Once the transceiver, wishing
to join the network, ascertains what it believes to
be the proper spread spectrum code, it transmits a
request to join the network during slot 0. The
request to join includes an identifying address.
When the HU receives a request to join the network,
it first looks for the identifying address in its
members list. If the SU appears on its list, the HU
returns a message that assigns the SU a slot number.
If not, it rejects the request. The member list
prevents SUs from one network accidentally joining
another network.

If the SU attempting to join the network is
denied access by the HU, or if it is responded to by
the wrong HU, it may repeat its request to join,
utilizing the other spread spectrum codes in its
wireless terminals. If after a predefined number of
attempts, it is still unable to join the network, it
then executes an SOS sequence. The SU is not
synchronized with the HU during an SOS transmission.
Therefore, a relatively long transmission is utilized

which enhances the chances of HU reception, despite
collisions and lack of synchronization. If the SU
receives an ISP from the correct HU, then it joins
the network. Otherwise, after a defined number of
SOS attempts, it becomes inactive.

Because SUs may be at varying distances from
their HU, SU to HU transmission signal delays may
differ for each SU. Additionally, the required
transmission power at each SU, which ensures reliable
HU reception may also differ. Therefore, once
communication is established, the transmission power
level and time delay is fine tuned. The particular
SU being initialized transmits Transmitter Test
Packets (TTPs) to its HU, at a plurality of
power-delay combinations. The HU selects the best
power as the lowest level which has a signal quality
exceeding a defined threshold, or if none exceeds the
threshold, then the highest quality power level. The
best delay is selected as the one which provides the
best timing results, with respect to the predefined
time frame, at the selected power level. Both power
level and transmission signal delay may be
dynamically modified subsequent to a SU joining the
network.

The criteria for selecting the particular
spread spectrum code to be used and for setting the
gain control for the HU receiver is that combination
which results in minimum noise in the received
signal. The HU determines the proper combination by
monitoring the up-link channel from its associated
SUs and tracking the rate of falsely detected.
transmission requests with respect to each potential

gain and code combination. If the HU changes the
particular spread spectrum code being used over the
network it must inform all SUs by transmitting an ISP.

The HU to SU transmission power is adjusted
based on SU reception statistics. For example if the
stations are receiving a number of erroneous
transmissions from the HU then the power level at the
HU is increased. The HU transmitter power is also
adjusted based on signal quality index measurements
taken at each SU. These, like those taken at the HU
during the SU power adjustment, involve comparing the
received signal to an acceptable threshold level.

The invention may be embodied in other
specific forms without departing from the spirit or
essential characteristics thereof. The present
embodiments are therefore to be considered in all
respects as illustrative and not restrictive, the
scope of the invention being indicated by the
appended claims rather than by the foregoing
description, and all changes which come within the
meaning and range of equivalency of the claims are
therefore intended to be embraced therein.

Claims

1.   A multiple access communications system,
comprising

        A.   at least one hub unit,

        B.   at least one station unit associated
with each of said hub units,

        C.   link means for establishing a
bidirectional communications link between each of
said hub units and its associated station units, said
link means including:

        downlink means for establishing a
unidirectional downlink radio frequency signal path
from each of said hub units to all of its associated
station units at a first predetermined frequency,

        uplink means for establishing a
unidirectional uplink radio frequency signal path
from each of said station units to its associated hub
unit at a second predetermined frequency,

        synchronization means for establishing
a common slotted time frame for each of said hub
units and its associated station units, and for
allocating subsets of the slots of said time frame to
each of said associated station units, and

        verification means for verifying,
within a predetermined number of said slots of said
time frame, the integrity of said bidirectional

communications link between each of said hub units
and its associated station units, wherein said
predetermined number is less than the total number of
slots in said time frame.

2.   A system according to claim 1 wherein said
link means further includes:

        uplink transmit means at each of said
station units, said uplink transmit means being
operative in said station unit's subset of time slots
of said time frame for selectively transmitting
station unit signals over said uplink radio frequency
signal path to said hub unit associated with said
station unit,

        HU receive means at each of said hub
units for receiving said station unit signals from
its associated station units via said uplink radio
frequency signal path,

        downlink transmit means at each of said
hub units, said downlink transmit means being
operative in response to said received station unit
signals from each of its associated station units for
transmitting hub unit signals corresponding to said
received station unit signals over said downlink
radio frequency signal path to each of its associated
station units,

        SU receive means at each of said
station units for receiving said hub unit signals
from its associated hub unit via said downlink radio
frequency signal path,

verification means at each of said
station units for comparing said transmitted station
unit signals and corresponding received station unit
signals, and

error means responsive to said
comparison for generating an error signal when said
transmitted station unit signals and said
corresponding received station unit signals fail to
be characterized by a predetermined correlation.

3.   A system according to claim 1 wherein said
link means further comprises

SU uplink conversion means at each of
said station units for converting, from a baseband
digital format to a direct sequence spread spectrum
format, said station unit signals to be transmitted,

HU uplink conversion means at each of
said hub units for converting, from a direct sequence
spread spectrum format to a baseband digital format,
said received station unit signals,

HU downlink conversion means at each of
said HU's for converting, from a baseband digital
format to a direct sequence spread spectrum format,
said hub unit signals to be transmitted from said hub
units to said associated station units,

SU downlink conversion means at each of
said station units for converting, from direct
sequence spread spectrum format to a baseband digital
format, said received hub unit signals.

4.   A system according to claim 3 wherein

        said SU uplink conversion means further
includes means for converting, from a baseband format
to a phase modulated format, said transmitted station
unit signals,

        said HU uplink conversion means further
includes means for converting, from a phase modulated
format to a baseband format, said received station
unit signals,

        said HU downlink conversion means
further includes means for converting, from a
baseband format to a phase modulated format, said
transmitted HU signals, and

        said SU downlink conversation means
further includes means for converting, form a phase
modulated format to a baseband format, said received
HU signals.

5.   A system according to claim 1 wherein said
link means further includes uplink availability
detector at each of said station units, said uplink
availability detector including:

        means for monitoring said downlink
radio frequency signal path from its associated hub
unit and

        LBT means responsive to said monitoring
means for determining availability of said uplink
radio frequency signal path prior to transmitting a

signal from said station unit to its associated hub
unit via said uplink radio frequency signal path.

6.   A system according to claim 5 wherein said
LBT means includes means for identifying periods when
[criteria] such periods being indicative of permitted
transmission by said station unit.

7.   A system according to claim 1 wherein said
link means further includes uplink unavailability
detector at each of said station units, said uplink
unavailability detector including:

          means for monitoring said downlink
radio frequency signal path from said hub unit during
transmission of said station unit signals by said
station unit to its associated hub unit over said
uplink radio frequency signal path and

          LWT means for detecting if the hub unit
becomes unavailable to said station unit during said
transmission.

8.   A system according to claim 7 wherein said
LWT means includes means for identifying [criteria,
e.g. collisions]

9.   A system according to claim 1 further
including station unit transmission signal power
adjustment means for adaptively controlling
transmission signal power for at least one of said
station units whereby said transmission signal power
level from said station unit is substantially at a
predetermined level at its associated hub unit.

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10.   A system according to claim 9 wherein the
transmission signal power levels of said station
units at their associated hub unit are controlled to
be substantially equal.

11.   A system according to claim 1 further
including hub unit transmission signal power
adjustment means for adaptively controlling
transmission signal power at least one of said hub
units whereby transmission signal power level from
said hub unit is substantially at a predetermined
level at a selected one of said station units
associated therewith.

12.   A system according to claim 11 wherein said
selected one of said station units is the station
unit farthest away from said hub unit.

13.   A system according to claim 1 further
including station unit transmission signal delay
adjustment means for adaptively controlling
transmission signal delay for at least one of said
station units whereby transmissions from said station
units occur substantially at a predetermined time
within said time frame at said hub unit.

14.   A system according to claim 1 wherein said
link means further includes hub unit retransmission
means at said hub units for retransmitting from said
hub units to each of said associated station units
over said downlink radio signal path, substantially
all communications received by said hub unit from
each of said associated station units via said uplink
radio signal path.

15.   A system according to claim 1 further
including

         a backbone communications bus and

         a plurality of network interface units
coupled along said bus wherein at least one of said
hub units is coupled to and in communications with
said bus, said coupling being through an associated
network interface unit.

16.   A system according to claim 15 wherein said
backbone is wireless.

17.   A system according to claim 15 wherein said
backbone is fiber optically connected.

18.   A system according to claim 15 wherein said
backbone employs a token passing ring protocol.

19.   A system according to claim 15 wherein said
backbone employs an ethernet protocol.

20.   A system according to claim 15 wherein said
backbone is hard wired.

21.   A multiple access communications system,
comprising

         A.   at least one hub unit

         B.   at least one station unit associated
with each of said hub units

C.   link means for establishing a
bidirectional communications link between each of
said hub units and its associated station units, said
link means including

        downlink means for establishing a
unidirectional downlink radio frequency signal path
from each of said hub units to all of its associated
station units at a first predetermined frequency,

        uplink means for establishing a
unidirectional uplink radio frequency signal path
from each of said station units to its associated hub
unit at a second predetermined frequency, and

        synchronization means for establishing
a common slotted time frame for each of said hub
units and its associated station units, and for
allocating subsets of the slots of said time frame to
each of said associated station units.

22.   A multiple access communications system
operating over a predetermined region, comprising:

        A.   at least one hub unit,

        B.   at least one station unit associated
with each of said hub units,

        C.   link means for establishing a
bidirectional wireless communications link between
each of said hub units and its associated station
units, said communications link supporting a data
rate, R,

said link means including:

i)   downlink means for establishing at
least one wireless downlink radio frequency signal
path for transferring information from each of said
hub units to all of its associated station units at a
first predetermined frequency, f_1,

ii)   uplink means for establishing at
least one wireless uplink radio frequency signal path
for transferring information from each of said
station units to its associated hub unit at a second
predetermined frequency, f_2,

wherein f_1 and f_2 are frequencies at
which signal reflections from local objects may exist
within said region such that a plurality of said
uplink and said downlink radio frequency signal paths
may occur between a particular hub unit and an
associated station unit,

each of said signal paths having an
associated signal delay for a signal passing over
said path, said associated delay varying in
proportion to said signal path's deviation in length
from that of a theoretical straight line path between
said particular hub unit and said associated station
unit,

said signal path having the greatest of
said deviations in length being associated with a
maximum delay, D_{max}, wherein D_{max} is a predetermined
portion of $1/R$,

iii) recovery means, responsive to said
signals passing between said particular hub unit and
said associated station unit, over said plurality of
paths, for regenerating said information transferred
between said hub unit and said associated station
unit, and

iv) synchronization means for
establishing a common slotted time frame for each of
said hub units and its associated station units, and
for allocating subsets of the slots of said time
frame to each of said associated station units.

1.   A multiple access communications system,
comprising

    A.   one or more hub units,

    B.   a plurality of station units associated
with each of said hub units,

    C.   link means for establishing a
bidirectional communications link between each of
said hub units and its associated station units, said
link means including:

        i)   downlink means for establishing a
unidirectional downlink radio frequency signal path
from each of said hub units to all of its associated
station units at a first predetermined frequency,

        ii)   uplink means for establishing a
unidirectional uplink radio frequency signal path
from each of said station units to its associated hub
unit at a second predetermined frequency,

        iii) synchronization means, selectively
operative in a first mode, for establishing a common
slotted time frame for each of said hub units and its
associated station units, said time frame defining a
plurality of time slots, and for allocating subsets
of said time slots to each of said associated station
units, and selectively operative in a second mode,
for allocating sole access to said uplink radio

frequency signal path to one of said associated
station units, in response to receipt of an access
request signal from said one station unit in a time
slot included in said subset of time slots allocated
to said one station unit,

　　　　verification means for verifying,
within a predetermined number of said time slots, the
integrity of said bidirectional

signal from said station unit to its associated hub
unit via said uplink radio frequency signal path.

6.   A system according to claim 5 wherein said
LBT means includes means for identifying periods when
[criteria] such periods being indicative of permitted
transmission by said station unit.

7.   A system according to claim 1 wherein said
link means further includes uplink unavailability
detector at each of said station units, said uplink
unavailability detector including:

        means for monitoring said downlink
radio frequency signal path from said hub unit during
transmission of said station unit signals by said
station unit to its associated hub unit over said
uplink radio frequency signal path and

        LWT means for detecting if the hub unit
becomes unavailable to said station unit during said
transmission.

8.   A system according to claim 7 wherein said
LWT means includes means for identifying collisions.

9.   A system according to claim 1 further
including station unit transmission signal power
adjustment means for adaptively controlling
transmission signal power for at least one of said
station units whereby said transmission signal power
level from said station unit is substantially at a
predetermined level at its associated hub unit.

15.   A system according to claim 1 further
including

              a backbone communications bus and

              a plurality of network interface units
coupled along said bus wherein at least one of said
hub units is coupled to and in communications with
said bus, said coupling being through an associated
network interface unit.

16.   A system according to claim 15 wherein said
backbone is wireless.

17.   A system according to claim 15 wherein said
backbone is fiber optically connected.

18.   A system according to claim 15 wherein said
backbone employs a token passing ring protocol.

19.   A system according to claim 15 wherein said
backbone employs an ethernet protocol.

20.   A system according to claim 15 wherein said
backbone is hard wired.

21.   A multiple access communications system,
comprising

         A.   one or more hub units

         B.   a plurality of station units associated
with each of said hub units

C.   link means for establishing a
bidirectional communications link between each of
said hub units and its associated station units, said
link means including

        i)   downlink means for establishing a
unidirectional downlink radio frequency signal path
from each of said hub units to all of its associated
station units at a first predetermined frequency,

        ii)   uplink means for establishing a
unidirectional uplink radio frequency signal path
from each of said station units to its associated hub
unit at a second predetermined frequency, and

        iii) synchronization means, selectively
operative in a first mode, for establishing a common
slotted time frame for each of said hub units and its
associated station units, said time frame defining a
plurality of time slots, and for allocating subsets
of said time slots to each of said associated station
units, and selectively operative in a second mode,
for allocating sole access to said uplink radio
frequency signal path to one of said associated
station units, in response to receipt of an access
request signal from said one station unit in a time
slot included in said subset of time slots allocated
to said one station unit.

22.   A multiple access communications system
operating over a predetermined region, comprising:

    A.   one or more hub units,

     B.   a plurality of station units associated with each of said hub units,

     C.   link means for establishing a bidirectional wireless communications link between each of said hub units and its associated station units, said communications link supporting a data rate, R,

said link means including:

i)   downlink means for establishing at
least one wireless downlink radio frequency signal
path for transferring information from each of said
hub units to all of its associated station units at a
first predetermined frequency, f_1,

ii)   uplink means for establishing at
least one wireless uplink radio frequency signal path
for transferring information from each of said
station units to its associated hub unit at a second
predetermined frequency, f_2,

wherein f_1 and f_2 are frequencies at
which signal reflections from local objects may exist
within said region such that a plurality of said
uplink and said downlink radio frequency signal paths
may occur between a particular hub unit and an
associated station unit,

each of said signal paths having an
associated signal delay for a signal passing over
said path, said associated delay varying in
proportion to said signal path's deviation in length
from that of a theoretical straight line path between
said particular hub unit and said associated station
unit,

said signal path having the greatest of
said deviations in length being associated with a
maximum delay, D_{max}, wherein D_{max} is a predetermined
portion of $1/R$,

iii) recovery means, responsive to said signals passing between said particular hub unit and said associated station unit, over said plurality of paths, for regenerating said information transferred between said hub unit and said associated station unit, and

iv) synchronization means, selectively operative in a first mode, for establishing a common slotted time frame for each of said hub units and its associated station units, said time frame defining a plurality of time slots, and for allocating subsets of said time slots to each of said associated station units, and selectively operative in a second mode, for allocating sole access to said uplink radio frequency signal path to one of said associated station units, in response to receipt of an access request signal from said one station unit in a time slot included in said subset of time slots allocated to said one station unit.

23.   A system according to claim 1 wherein said link means further includes controller means for selecting between said first mode and said second mode, and wherein said controller means includes means for transitioning from said first mode to said second mode in response to said hub unit receiving an request signal from one of said associated station units.

24.   A system according to claim 1 wherein said subset includes at least one pair of associated time slots in said time frame, and said pair includes a first occurring time slot and a second occurring time slot, wherein each of said station units can request access to said uplink radio frequency signal path during said first occurring time slot and can receive acknowledgement of being granted said access during said second occurring time slot, said first occurring time slot being spaced in time from said second occurring time slot by a period of time equal to or greater than a minimum two-way radio frequency transit time between said hub unit and said associated station unit.

25.   A system according to claim 1 wherein each of said subsets include at least one pair of associated time slots in said time frame, each pair including a first occurring time slot and a second occurring time slot, said first occurring time slot being spaced in time from said second occurring time slot by a period of time equal to or greater than a minimum two-way radio frequency transit time between said hub unit and said associated station unit, and wherein

A.   each of said associated station units include

　　　　　　　　　i)　　means for transmitting an access
request signal to said hub unit over said uplink
radio frequency signal path during said first
occurring time slot of one of its pairs of associated
time slots to request sole access to said uplink
radio frequency channel,

　　　　　　　　　ii)　means for receiving, over said
downlink radio frequency signal path during said
second occurring time slot of said one pair, an
allocation signal representative of a grant of sole
access to said uplink radio frequency signal path, and

　　　　B.　　said hub unit includes

　　　　　　　　　i)　　means for receiving said access
request signal over said uplink radio frequency
signal path,

　　　　　　　　　ii)　　means for identifying which one of
said associated station units originated said access
request signal by identifying the one of said pairs
of said time slots during which said access request
code was received at said hub unit, and

　　　　　　　　　iii) means for selectively transmitting
said allocation signal to said identified station
unit over said downlink radio frequency signal path
during said second occurring time slot of said
identified pair.

26.   A system according to claim 25 wherein said
link means further includes controller means for
selecting between said first mode and said second
mode, and wherein said controller means includes
means for transitioning from said first mode to said
second mode in response to said hub unit receiving
said access request signal from said identified
station unit.

27.   A system according to claim 1 wherein said
associated station units include means for
transmitting (m) characters to said hub unit over
said uplink radio frequency signal path during said
second mode of operation, where (m) is an integer
less than a predetermined number.

28.   A system according to claim 1 wherein said
associated station units include means for
transmitting (n) packets of information to said hub
unit over said uplink radio frequency signal path
during said second mode of operation, where (n) is an
integer less than a predetermined number.

29.   A system according to claim 28 wherein each
said packets of information include a selectable
number of characters, and said associated station
units include means for selecting said number of
characters included in each of said packets in
response to a control command from said hub unit.

30.   A system according to claim 28 wherein said
associated station units include means for selecting
(n) in response to a control command from said hub
unit.

31.   A system according to claim 1 wherein said
synchronization means further includes means for
signaling said associated station units as to which
of said allocated subsets of times slots will be a
first to occur upon transitioning from said second
mode of operation to said first mode operation.

32.   A system according to claim 21 wherein said
link means further includes controller means for
selecting between said first mode and said second
mode, and wherein said controller means includes
means for transitioning from said first mode to said
second mode in response to said hub unit receiving an
request signal from one of said associated station
units.

33.   A system according to claim 21 wherein said
subset includes at least one pair of associated time
slots in said time frame, and said pair includes a
first occurring time slot and a second occurring time
slot, wherein each of said station units can request
access to said uplink radio frequency signal path
during said first occurring time slot and can receive
acknowledgement of being granted said access during
said second occurring time slot, said first occurring

time slot being spaced in time from said second
occurring time slot by a period of time equal to or
greater than a minimum two-way radio frequency
transit time between said hub unit and said
associated station unit.

34.   A system according to claim 21 wherein each
of said subsets include at least one pair of
associated time slots in said time frame, each pair
including a first occurring time slot and a second
occurring time slot, said first occurring time slot
being spaced in time from said second occurring time
slot by a period of time equal to or greater than a
minimum two-way radio frequency transit time between
said hub unit and said associated station unit, and
wherein

      A.   each of said associated station units
include

            i)   means for transmitting an access
request signal to said hub unit over said uplink
radio frequency signal path during said first
occurring time slot of one of its pairs of associated
time slots to request sole access to said uplink
radio frequency channel,

            ii)   means for receiving, over said
downlink radio frequency signal path during said
second occurring time slot of said one pair, an
allocation signal representative of a grant of sole
access to said uplink radio frequency signal path, and

      B.   said hub unit includes

           i)   means for receiving said access request signal over said uplink radio frequency signal path,

           ii)   means for identifying which one of said associated station units originated said access request signal by identifying the one of said pairs of said time slots during which said access request code was received at said hub unit, and

           iii) means for selectively transmitting said allocation signal to said identified station unit over said downlink radio frequency signal path during said second occurring time slot of said identified pair.

35.   A system according to claim 34 wherein said link means further includes controller means for selecting between said first mode and said second mode, and wherein said controller means includes means for transitioning from said first mode to said second mode in response to said hub unit receiving said access request signal from said identified station unit.

36.   A system according to claim 21 wherein said associated station units include means for transmitting (m) characters to said hub unit over said uplink radio frequency signal path during said second mode of operation, where (m) is an integer less than a predetermined number.

37.   A system according to claim 21 wherein said
associated station units include means for
transmitting (n) packets of information to said hub
unit over said uplink radio frequency signal path
during said second mode of operation, where (n) is an
integer less than a predetermined number.

38.   A system according to claim 37 wherein each
said packets of information include a selectable
number of characters, and said associated station
units include means for selecting said number of
characters included in each of said packets in
response to a control command from said hub unit.

39.   A system according to claim 37 wherein said
associated station units include means for selecting
(n) in response to a control command from said hub
unit.

40.   A system according to claim 21 wherein said
synchronization means further includes means for
signaling said associated station units as to which
of said allocated subsets of times slots will be a
first to occur upon transitioning from said second
mode of operation to said first mode operation.

41.   A system according to claim 22 wherein said
link means further includes controller means for
selecting between said first mode and said second

mode, and wherein said controller means includes
means for transitioning from said first mode to said
second mode in response to said hub unit receiving an
request signal from one of said associated station
units.

42.   A system according to claim 22 wherein said
subset includes at least one pair of associated time
slots in said time frame, and said pair includes a
first occurring time slot and a second occurring time
slot, wherein each of said station units can request
access to said uplink radio frequency signal path
during said first occurring time slot and can receive
acknowledgement of being granted said access during
said second occurring time slot, said first occurring
time slot being spaced in time from said second
occurring time slot by a period of time equal to or
greater than a minimum two-way radio frequency
transit time between said hub unit and said
associated station unit.

43.   A system according to claim 22 wherein each
of said subsets include at least one pair of
associated time slots in said time frame, each pair
including a first occurring time slot and a second
occurring time slot, said first occurring time slot
being spaced in time from said second occurring time
slot by a period of time equal to or greater than a
minimum two-way radio frequency transit time between
said hub unit and said associated station unit, and
wherein

A.   each of said associated station units
include

i)   means for transmitting an access
request signal to said hub unit over said uplink
radio frequency signal path during said first
occurring time slot of one of its pairs of associated
time slots to request sole access to said uplink
radio frequency channel,

ii)   means for receiving, over said
downlink radio frequency signal path during said
second occurring time slot of said one pair, an
allocation signal representative of a grant of sole
access to said uplink radio frequency signal path, and

B.   said hub unit includes

i)   means for receiving said access
request signal over said uplink radio frequency
signal path,

ii)   means for identifying which one of
said associated station units originated said access
request signal by identifying the one of said pairs
of said time slots during which said access request
code was received at said hub unit, and

iii) means for selectively transmitting
said allocation signal to said identified station
unit over said downlink radio frequency signal path
during said second occurring time slot of said
identified pair.

44.   A system according to claim 43 wherein said
link means further includes controller means for
selecting between said first mode and said second
mode, and wherein said controller means includes
means for transitioning from said first mode to said
second mode in response to said hub unit receiving
said access request signal from said identified
station unit.

45.   A system according to claim 22 wherein said
associated station units include means for
transmitting (m) characters to said hub unit over
said uplink radio frequency signal path during said
second mode of operation, where (m) is an integer
less than a predetermined number.

46.   A system according to claim 22 wherein said
associated station units include means for
transmitting (n) packets of information to said hub
unit over said uplink radio frequency signal path
during said second mode of operation, where (n) is an
integer less than a predetermined number.

47.   A system according to claim 46 wherein each
said packets of information include a selectable
number of characters, and said associated station
units include means for selecting said number of
characters included in each of said packets in
response to a control command from said hub unit.

48.   A system according to claim 46 wherein said
associated station units include means for selecting
(n) in response to a control command from said hub
unit.

49.   A system according to claim 22 wherein said
synchronization means further includes means for
signaling said associated station units as to which
of said allocated subsets of times slots will be a
first to occur upon transitioning from said second
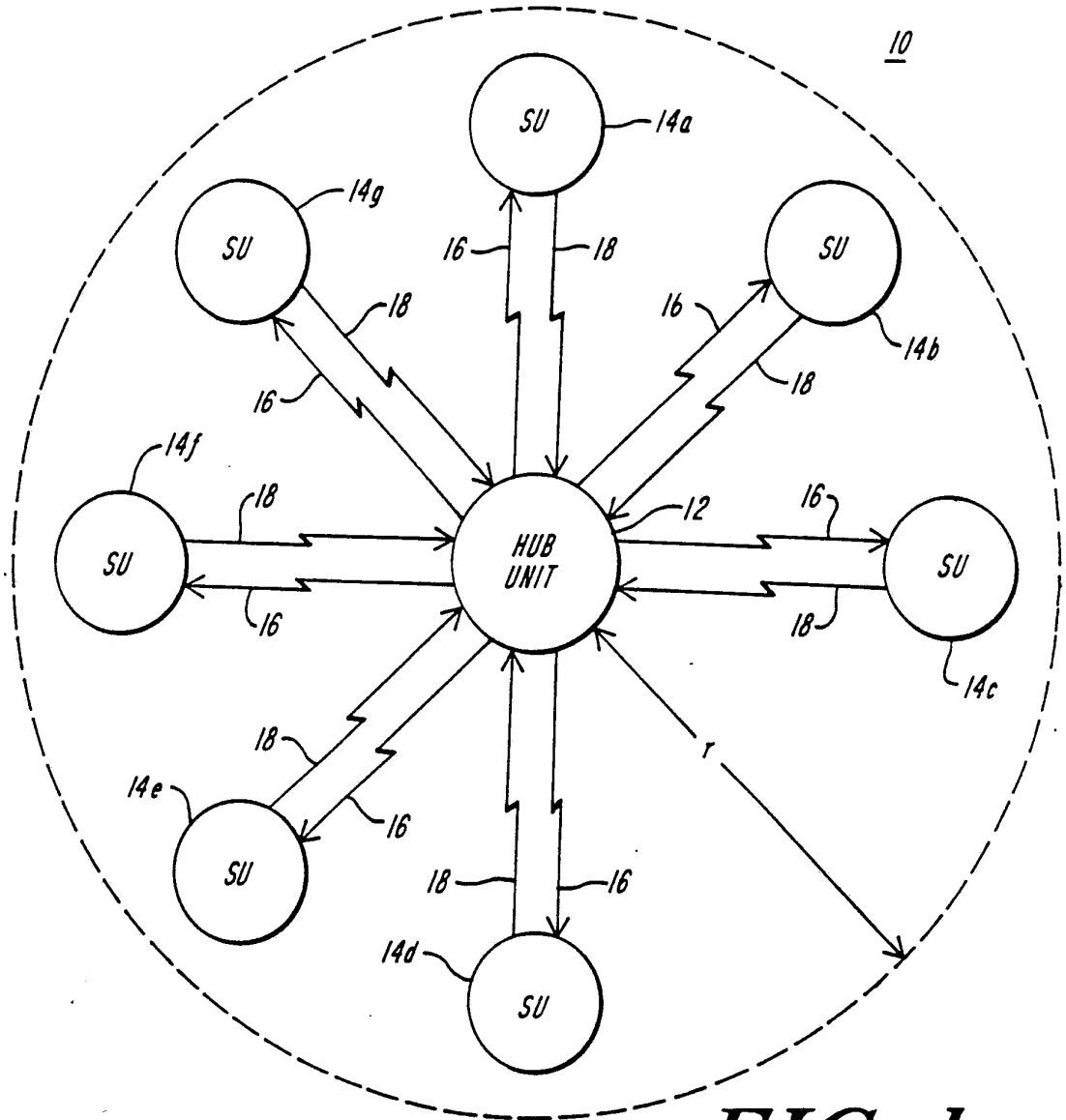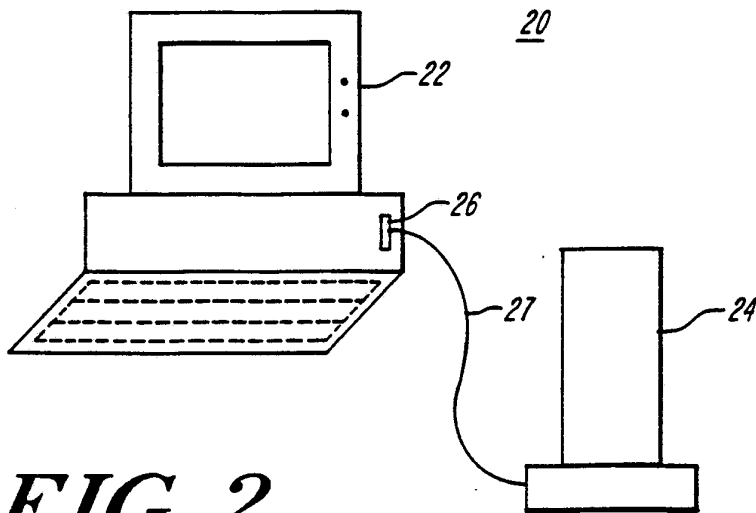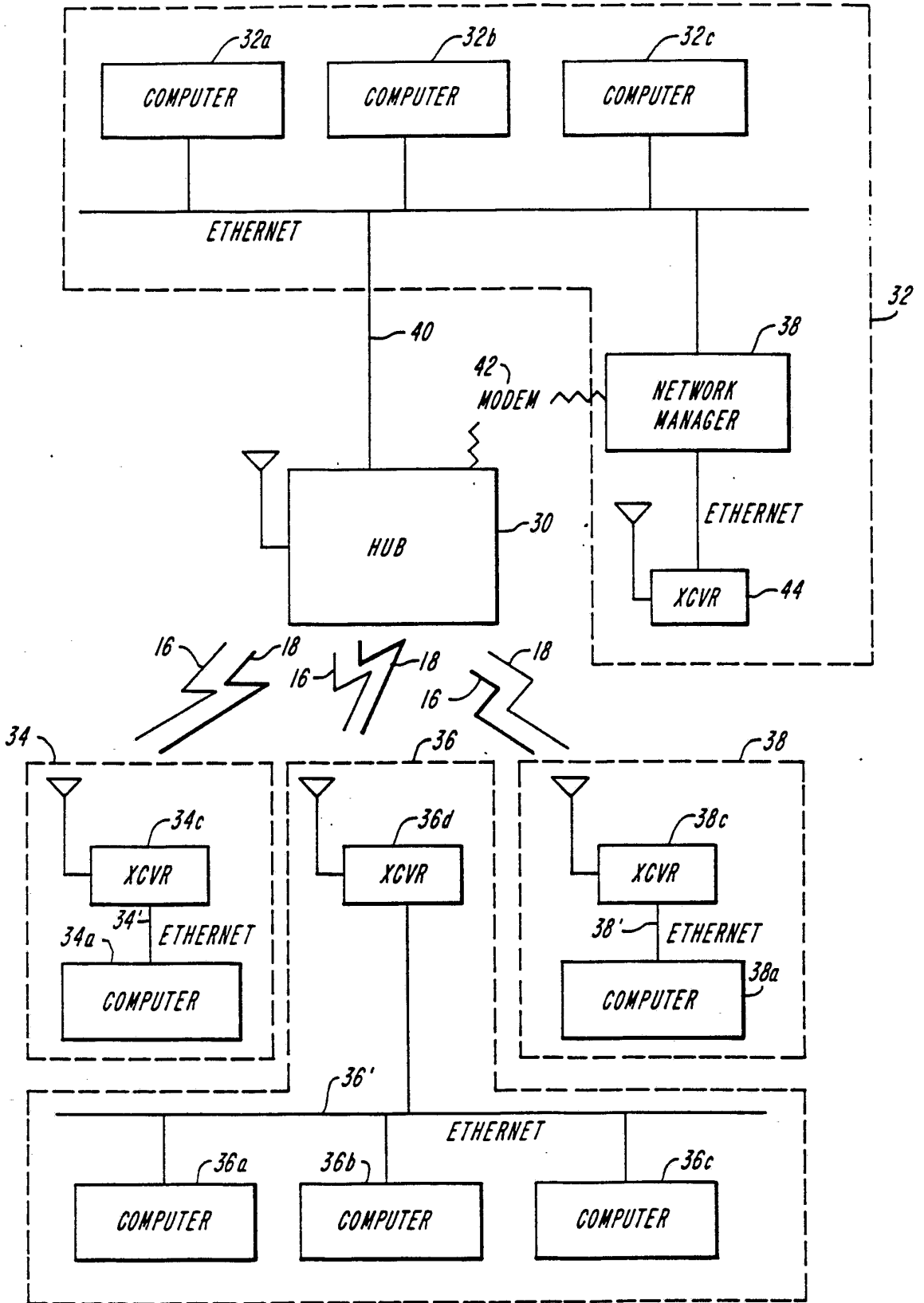mode of operation to said first mode operation.

FIG. 1

FIG. 2

FIG. 3
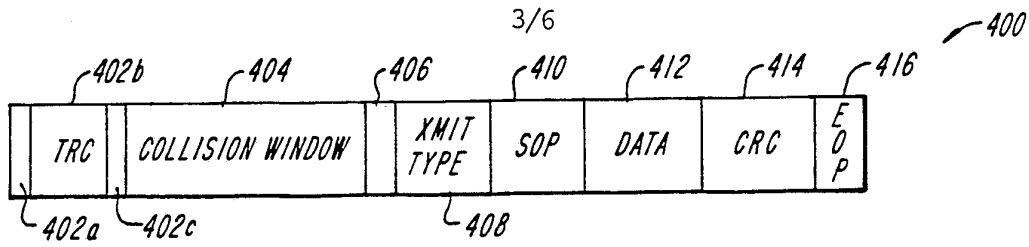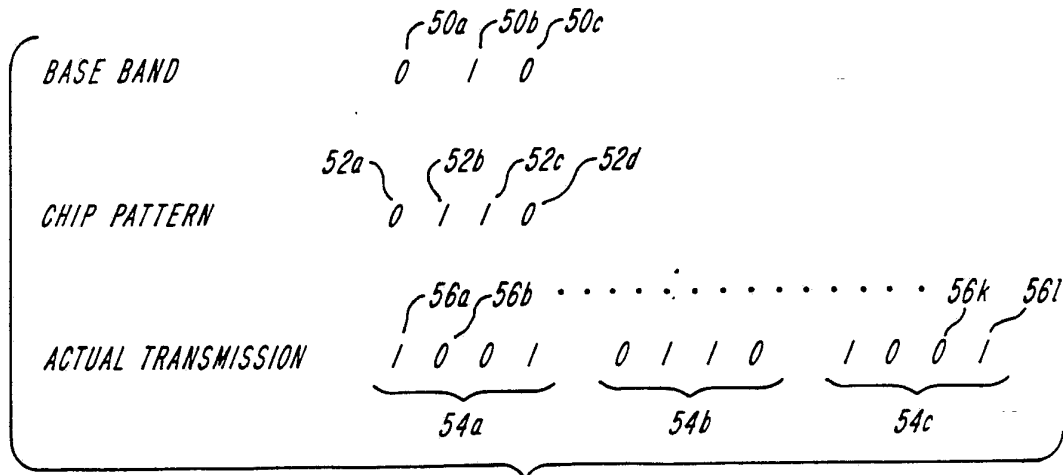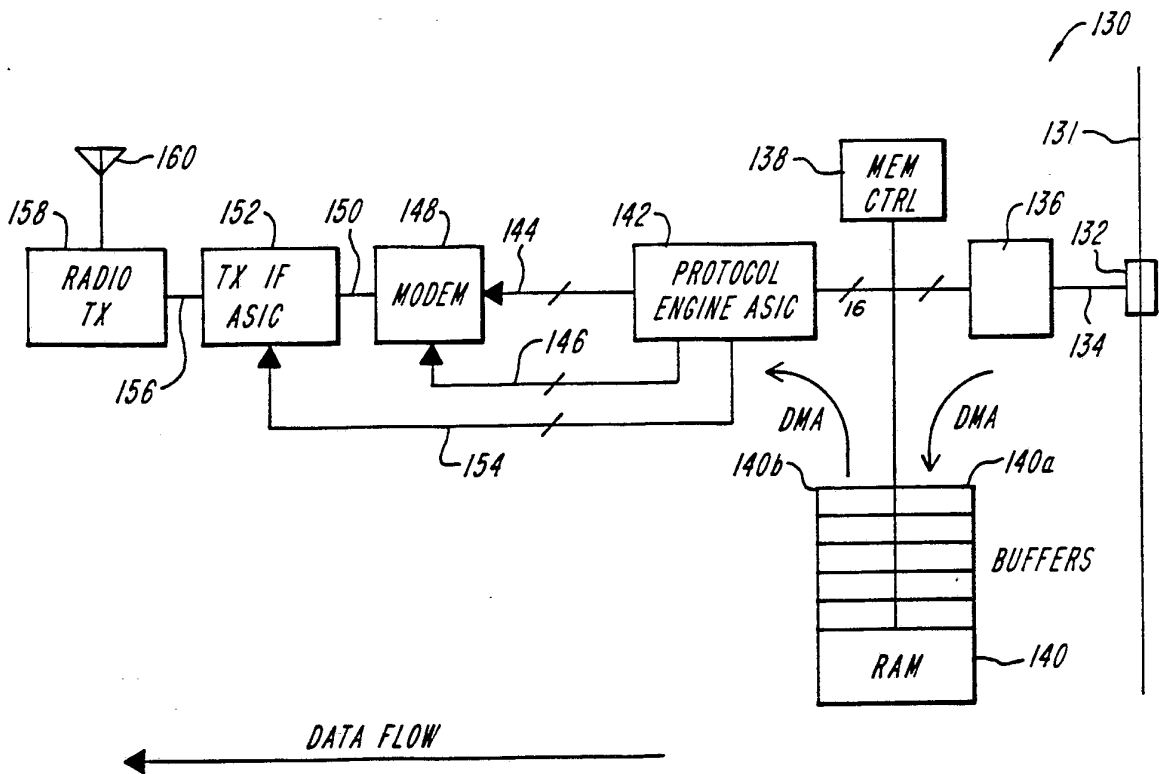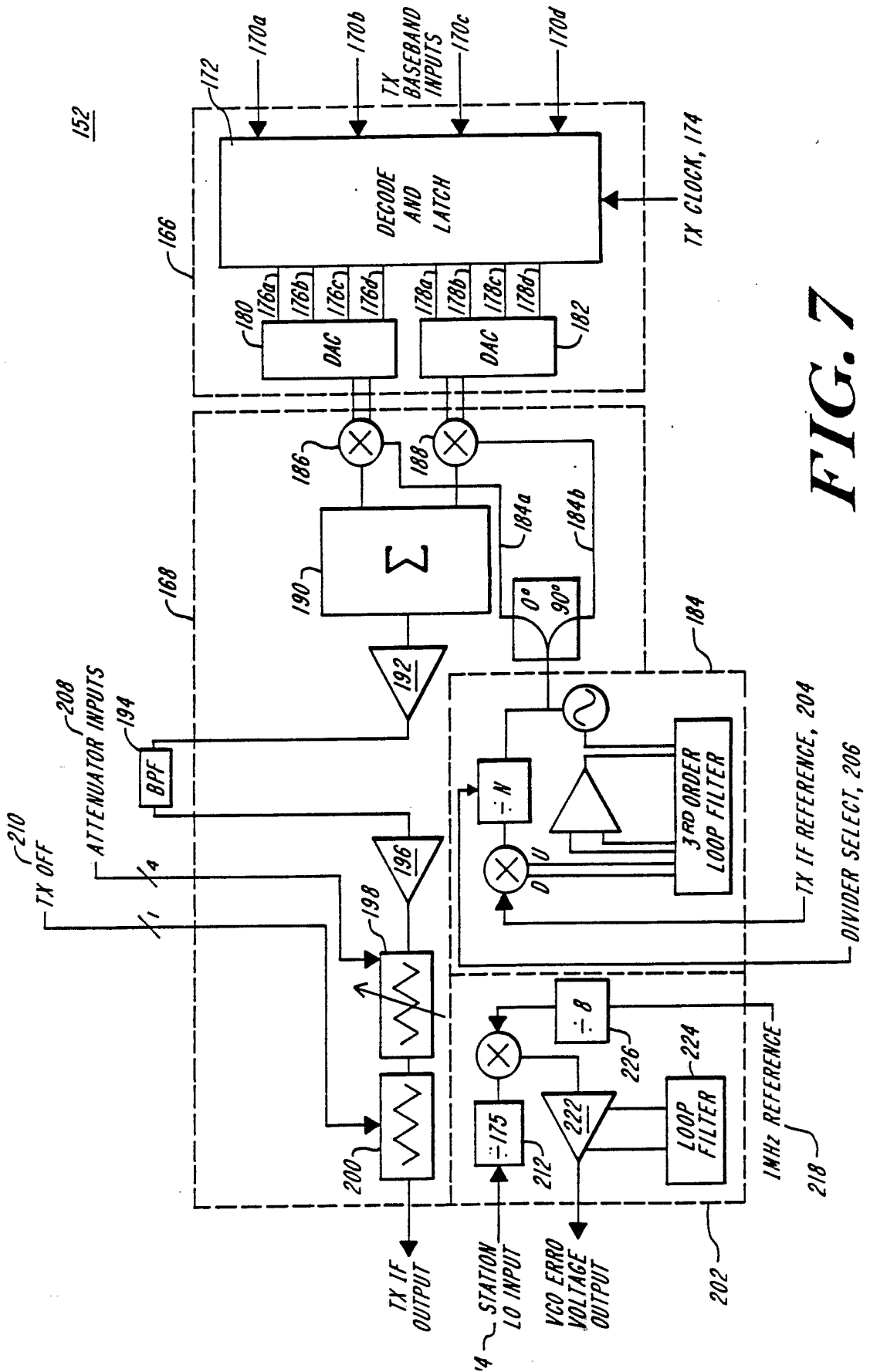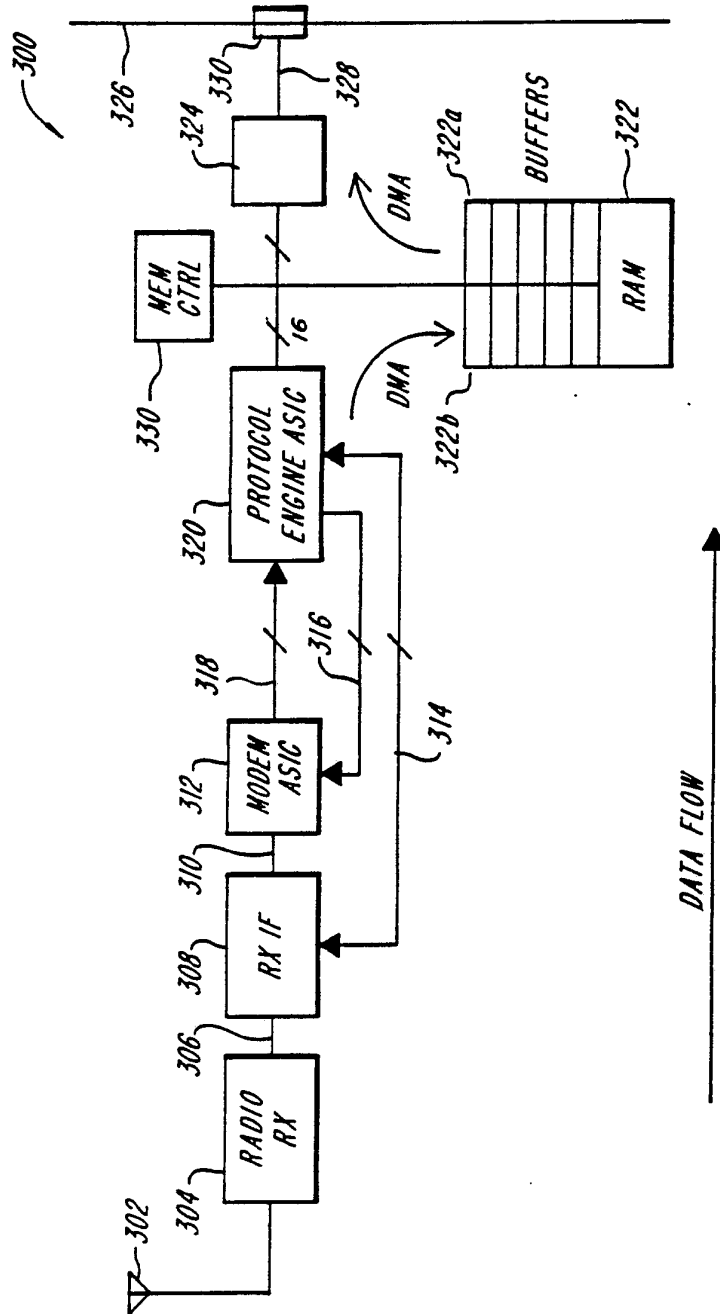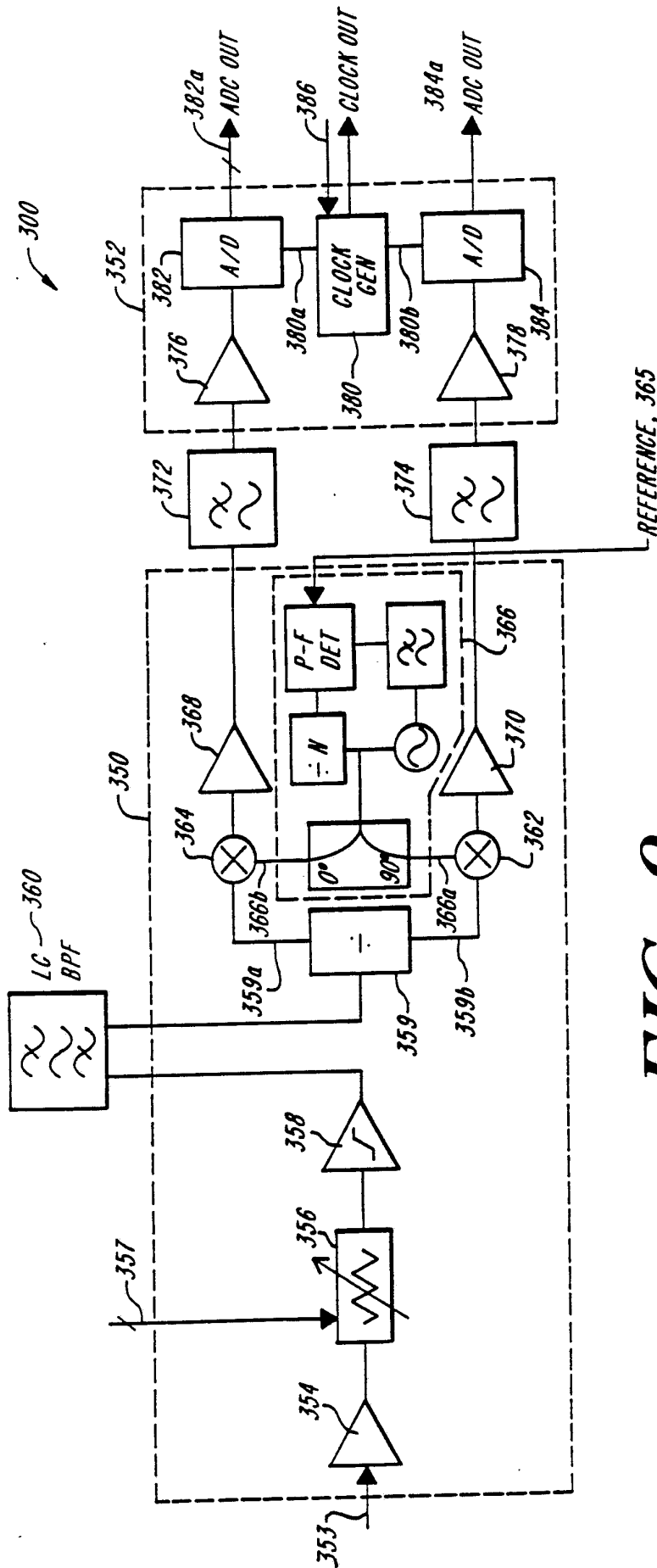
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FIG. 4

FIG. 5

DATA FLOW

FIG. 6

FIG. 7

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FIG. 8

FIG. 9

INTERNATIONAL SEARCH REPORT

A.	CLASSIFICATION OF SUBJECT MATTER

IPC(5)   :H04B 15/00
US CL   :375/1

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. :   380/34

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 practicable, search terms used)

C.	DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US,A, 3,921,137 (McClearn, Jr. et al.) 18 November 1975 See entire document.	1-22
Y	US,A, 4,587,662 (Langewellpott) 06 May 1986 See entire document.	1-22
Y	US,A, 4,928,274 (Gilhouse et al) 22 May 1990, See entire document.	1-22
Y	US,A, 5,029,183 (Tymes) 02 July 1991, See entire document.	1-22
Y	Scientific American, September 1991, V. Cerf, "Network" See pages 74-81.	1-22

☐ 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)	"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
"O"	document referring to an oral disclosure, use, exhibition or other means		
"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
24 MARCH 1993	27 APR 1993

Name and mailing address of the ISA/US	Authorized officer
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