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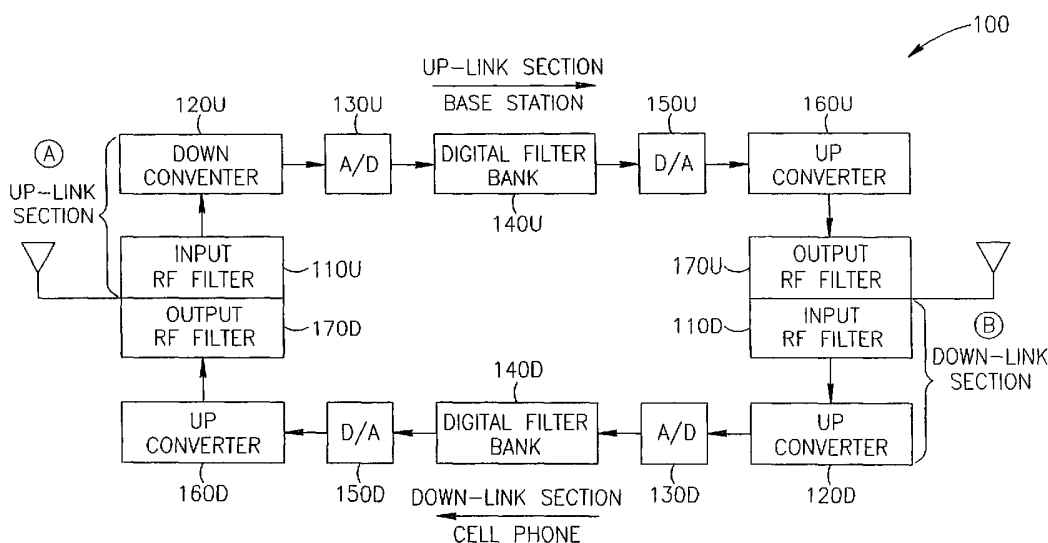
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(54) Title: REPEATER WITH DIGITAL CHANNELIZER



(57) Abstract: In order to retransmit a communication channel at a specific frequency, a receiver may receive a signal including the communication channel's specific frequency. An analog to digital converter may generate a digital signal correlated to the received signal and the digital signal may be passed through a digital filter configured to filter the digital signal and pass frequency components at or around the frequency of the communication channel's specific frequency. A digital to analog converter may generate an analog signal correlated to the filtered digital signal and a transmitter may transmit the analog signal.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

REPEATER WITH DIGITAL CHANNELIZER

FIELD OF THE INVENTION

The present invention relates generally to the field of communications.
5 More specifically, the present invention relates to a repeater for a communication or transmission system (e.g. bi-directional cellular communication systems).

BACKGROUND

Degradation of signal-to-noise ratio ("SNR") occurs to a signal carried
10 along a transmission medium (e.g. coax, unshielded conductor, wave guide, open air or even optical fiber). SNR degradation is one factor which may limit bandwidth over a transmission medium. In order to improve the SNR of signals being transmitted over long distances, and accordingly to augment the transmission distance and/or data rate, signal repeaters may be placed at
15 intervals along the transmitting path. Repeaters are well known and may be used for optical, microwave and radio frequency (RF) communication systems. Repeaters have been used as part of cellular transmission systems to extend the range of coverage between a cellular base station and a cellular handset.

However, the use of a repeater for one or more channels at one or more
20 frequencies within a shared frequency range of the spectrum (e.g. 800 MHz to 830 Mhz) may produce interference. Turning now to Fig. 1A, there is shown a spectral diagram exemplifying the channel frequencies a first cellular operator may be using within the frequency range of 800 to 830 MHz. Turning now to Fig. 1B, there is shown a spectral diagram exemplifying the channel frequencies a

second cellular operator in the same geographic location as the first may be using within the same frequency range, 800 to 830 MHz. As can be seen from the Figs. 1A and 1B, each operator's channel frequencies may be distinct from the other. However, two or more channel frequencies of one operator may either
5 be between two or more channel frequencies of the other operator or may be on either side one or more of the other operator's channel frequencies.

In order for an operator to use a repeater in the situation described above and exemplified in Figs. 1A and 1B, the operator would either need a separate response for each channel, or the operator may use a broader band repeater to
10 cover a frequency range within which several of the operator's channels reside. However, if a broader band repeater is used, the repeater may inadvertently retransmit one or more channels belonging to both operators. The retransmission of another operator's communication channel(s) has both legal and business implications which a cellular operator may prefer to avoid.

15 Analog channelized repeaters exist in the prior art. Channelized repeaters of the prior art use analog filters to exclude or filter out all signals or communication channels not belonging to the operator whose channels are to be repeated. For example, if the repeater's band of operation is 800 to 830 MHz, and the operator using the repeater has communication channels at 805 MHz,
20 807 MHz, and 809 MHz, the repeater may be equipped with analog filters which only allow or pass signals at the frequencies of the operator's channels. The analog channelized repeater thus retransmits only signals at the frequencies of the operator's communication channels.

Analog channelized repeaters of the prior art have numerous drawbacks which the present invention aims to address.

SUMMARY OF THE INVENTION

5 As part of the present invention, a receiver may receive a signal associated with a certain communication channel at a specific frequency. An analog to digital converter may generate a digital signal correlated to the received signal and the digital signal may be passed through a digital filter configured to filter the digital signal and pass frequency components at or around
10 the frequency of the communication channel's specific frequency. A digital to analog converter may generate an analog signal correlated to the filtered digital signal and a transmitter may transmit the analog signal.

 According to some embodiments of the present invention, there may be included a second digital filter configured to pass frequency components at or
15 around a second frequency associated with a second communication channel.

 According to some embodiments of the present invention, there may be included a down-converter to down-convert a received signal to an intermediate signal. An up-converter may also be included to up-convert to a transmission frequency an analog signal correlated to the filtered digital signal.

20

BRIEF DESCRIPTION OF THE DRAWINGS

 The subject matter regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of operation, together

with objects, features, and advantages thereof, may best be understood by reference to the following detailed description when read with the accompanying drawings in which:

Fig. 1A is a spectral diagram exemplifying four frequencies which may be used
5 by a first cellular operator for four communication channels in a specific geographic region;

Figs. 1B is a spectral diagram exemplifying three frequencies which may be used by a second cellular operator for three communication channels in a specific geographic region;

10 Fig. 2 is a block diagram showing an example of a bi-directional repeater with a digital channelizer according to some embodiment of the present invention;

Fig. 3 is a block diagram showing a more detailed view of the filter bank in Fig. 3;

Figs. 4A to 4D spectral diagrams showing examples of frequency responses of
15 the digital filters 140A through 140D in Fig. 3; and

Fig. 5 is a block diagram showing another example of a bi-directional repeater with a digital channelizer according to some embodiment of the present invention.

It will be appreciated that for simplicity and clarity of illustration, elements
20 shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements.

DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the present invention may be
5 practiced without these specific details. In other instances, well-known methods, procedures, components and circuits have not been described in detail so as not to obscure the present invention.

Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions
10 utilizing terms such as "processing", "computing", "calculating", "determining", or the like, refer to the action and/or processes of a computer or computing system, or similar electronic computing device, that manipulate and/or transform data represented as physical, such as electronic, quantities within the computing system's registers and/or memories into other data similarly represented as
15 physical quantities within the computing system's memories, registers or other such information storage, transmission or display devices.

Embodiments of the present invention may include apparatuses for performing the operations herein. This apparatus may be specially constructed for the desired purposes, or it may comprise a general purpose computer
20 selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs) electrically programmable read-only

memories (EPROMs), electrically erasable and programmable read only memories (EEPROMs), magnetic or optical cards, or any other type of media suitable for storing electronic instructions, and capable of being coupled to a computer system bus.

5 The processes and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct a more specialized apparatus to perform the desired method. The desired structure for a variety of these systems will appear
10 from the description below. In addition, embodiments of the present invention are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the inventions as described herein.

 As part of the present invention, a receiver may receive a signal
15 associated with a communication channel at a specific frequency. An analog to digital converter may generate a digital signal correlated to the received signal and the digital signal may be passed through a digital filter configured to filter the digital signal and pass frequency components at or around the frequency of the communication channel's specific frequency. A digital to analog converter may
20 generate an analog signal correlated to the filtered digital signal and a transmitter may transmit the analog signal.

 According to some embodiments of the present invention, there may be included a second digital filter configured to pass frequency components at or around a second frequency associated with a second communication channel.

According to some embodiments of the present invention, there may be included a down-converter to down-convert a received signal to an intermediate signal. An up-converter may also be included to up-convert to a transmission frequency an analog signal correlated to the filtered digital signal.

5 Turning now to Fig. 2, there is shown a block diagram of a bi-directional repeater 100 with a digital channelizer according to the present invention. The bi-directional repeater 100 may include two basic sections: (A) an upstream or up-link section which receives signals from a mobile device (e.g. cell phone) and retransmits the signal to a base-station; and (B) a downstream or down-link
10 section which receives signals from a base-station and retransmits the signals to a mobile device.

Looking first at the up-link section (A) from left to right on Fig. 2, there may be an input filter 110U, which for this example, may be a radio frequency ("RF") filter, or more specifically, may be a filter tuned to pass frequencies in the range
15 of 800 to 830 MHz, for example. The input RF filter 110U may receive signals from an antenna and may pass frequencies in the frequency range of one or more communication channels to be repeated to a down converter 120U. The down converter 120U may mix a received signal with a sine or cosine wave of a given frequency such that the received signal is down-converted to an
20 intermediate frequency ("IF"). Either the input RF filter 110U or the down converter 120U may include a signal amplifier (Not shown in Fig. 2). An analog to digital ("A/D") converter 130U may sample the IF signal and may generate a digital signal representing the sampled IF signal. The digital signal representing

the IF signal may enter digital filter bank 140U. Fig. 3 shows a more detailed view of digital filter bank 140U including digital filters 140a to 140d.

Turning now to Fig. 3, there is shown a block diagram of a digital filter bank 140U including digital filters 140a to 140d. A digital signal entering digital filter bank 140U may be applied to each of the digital filters 140a through 140d and the output of each of the digital filters may be combined by an adder 142 or by a functionally equivalent device. Each of the filters within the filter bank 140U may have a separate and distinct frequency response. Digital filters are well known in the field of communications. Implementation of a digital filter bank may be performed on a single or multiple processors (e.g. DSP) or may be implemented on a single or multiple dedicated digital filtering circuits. In the example of Fig. 3, there is shown four discrete digital filter circuits. As part of some embodiment of the present invention, digital filters 140a through 140d may be field programmable digital filters ("FPDF"). That is, each filter's transfer function, along with its frequency response, may be reprogrammed or adjusted.

Turning now to Figs. 4A through 4B, there are shown examples of possible frequency responses for digital filters 140a through 140d of Fig. 3, where digital filters 140a through 140b correspond to the first through the fourth communication channels exemplified in Fig. 1A, respectively. That is, the impulse response or frequency transfer characteristic for each digital filter 140a through 140d may be separately set or adjusted to pass frequency components of a digital signal that are at or around the carrier frequency of the filter's corresponding communication channel. For example; digital filter 140a may be programmed with a transfer function having a band pass frequency response

peaking at or around the carrier frequency of the first communication channel shown in Fig. 1A; Digital filter 140b may be programmed with a transfer function having a band pass frequency response peaking at or around the carrier frequency of the second communication channel shown in Fig. 1A, etc...

5

The design of digital filters and digital filter transfer functions is well known. Although specific filters and transfer functions are mentioned above, any digital filter and transfer function combination, currently known or to be devised in the future, may be used as part of the present invention.

10 Now turning back to Fig. 2, there is shown, directly after the digital filter bank 140U, a digital to analog converter ("D/A") 150U. The D/A 150U may convert the filtered digital signal output of the digital filter bank 140U to an analog signal, which analog signal may then be up-converted by up-converter 160U to the original frequency which was received at input RF filter 110U. An output filter
15 170U may be used to remove any harmonics which may have been introduced into the signal by the up-converter 160U. Either the up-converter 160U or the output RF filter 170U may include a signal amplifier (not shown in Fig. 2). The filtered signal may then propagate to and out of a transmission antenna.

The downstream or down-link (B) section of the bi-directional repeater
20 100 may almost mirror the up-stream section (A) discussed above. A difference being that the input RF filter 110D, digital filter bank 140D filters and output RF filter 170D may be tuned to receive and pass frequencies of downstream communication channels, as opposed to passing frequencies at or around upstream communication channels.

The specific frequency bands to which each of the filters is set may depend on the specific frequencies of the communication channels, upstream and downstream, an operator may wish to repeat within a specific geographic location. The frequencies shown in Fig. 1A and 1B are only examples of such communication channel frequencies. No distinction is made between upstream and downstream channels in Figs. 1A and 1B. However, it will be understood by one of ordinary skill in the art that in a cellular system, there may be a corresponding upstream communication channel for each downstream communication channel. The relation between upstream channel frequency and downstream channel frequency may be fixed, or each may be negotiated separately between a mobile device and a base station.

Turning now to Fig. 5, there is shown another possible embodiment of a bi-directional repeater 100 according to the present invention. As in the bi-directional repeater of Fig. 2, there are two sections; (A) an upstream or up-link section, and (B) a downstream or down-link section. Also, as in the embodiment of Fig. 2, the up-link and down-link sections may substantially mirror one another except for the frequencies they are tuned to pass and retransmit.

Looking at the downstream or down-link section (B) of the bi-directional repeater 100 of Fig. 5, there may be a duplexer including an input RF filter 110D. The input RF filter 110D may lead to a pre-filtering stage 115D which may include a low noise amplifier ("LNA") and an attenuator. The output of the pre-filtering block 115D may enter an RF unit 125D which may down convert the output and may also include an A/D converter. Digital filters in digital filter block 140D may be similar to the ones described for Figs. 2, 3 or 4A through 4D, or

may be any other digital filters suitable to the present invention. The output of the digital filter block 140D may enter the RF unit 125D which may up convert the output and may also include a D/A converter. A power amplifier block 145D may include an attenuator, a high-power amplifier, and a power monitor. An automatic gain control circuit ("AGC") may adjust the attenuator such that the output signal from the power amplifier block 145D remains substantially steady. The output signal of the power amplifier block 145D may propagate to and through a duplexer including an output filter 170D.

As for the bi-directional repeater 100 in Fig. 2, the bi-directional repeater 100 of Fig. 5 may be configured to repeat specific sets of communication channels, at or around specific carrier frequencies, in the upstream direction, and to repeat specific sets of communication channels, at or around specific carrier frequencies, in the downstream direction. Digital filters in the digital filter banks or block, 140U and 140D, may be adjusted to pass only frequencies at or around the carrier frequencies of the relevant communication channels. Carrier frequency offsets due to up-conversion or down-conversion may be taken into account and compensated for within the digital filters. Furthermore, the bi-directional repeater 100 of the present invention may be adjusted to notch out narrow band noise interference within the communication channels' frequency band.

While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes, and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the

appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

Claims

What is claimed:

1. A method of retransmitting a communication channel at a specific frequency, said method comprising:
 - 5 receiving a signal including the communication channel's specific frequency;
 - generating a digital signal correlated to the received signal;
 - filtering the digital signal with a digital filter configured to pass frequency components at or around the frequency of the communication
 - 10 channels specific frequency;
 - generating an analog signal correlated to the filtered digital signal; and
 - transmitting the analog signal correlated to the filtered digital signal.
2. The method according to claim 1, further comprising down-
 - 15 converting the received signal to an intermediate frequency prior to generating a digital signal.
3. The method according to claim 2, further comprising up-
 - converting the analog signal correlated to the filtered digital signal prior
 - 20 to transmitting the analog signal.
4. The method according to claim 1, further comprising filtering the digital signal with a digital filter configured to pass frequency

components at or around a second frequency associated with a second communication channel.

5. The method according to claim 4, further comprising
5 combining the digital signals out from each of said filtering steps and generating an analog signal correlated to the combined digital signal.

6. The method according to claim 5, further comprising
transmitting the analog signal correlated to the combined digital signal.

10

7. A system for retransmitting a communication channel at a specific frequency, said system comprising:

a receiver to receive a signal including the communication channel's specific frequency;

15 an analog to digital converter to generate a digital signal correlated to the received signal;

a digital filter configured to filter the digital signal and pass frequency components at or around the frequency of the communication channel's specific frequency;

20 a digital to analog converter to generate an analog signal correlated to the filtered digital signal; and

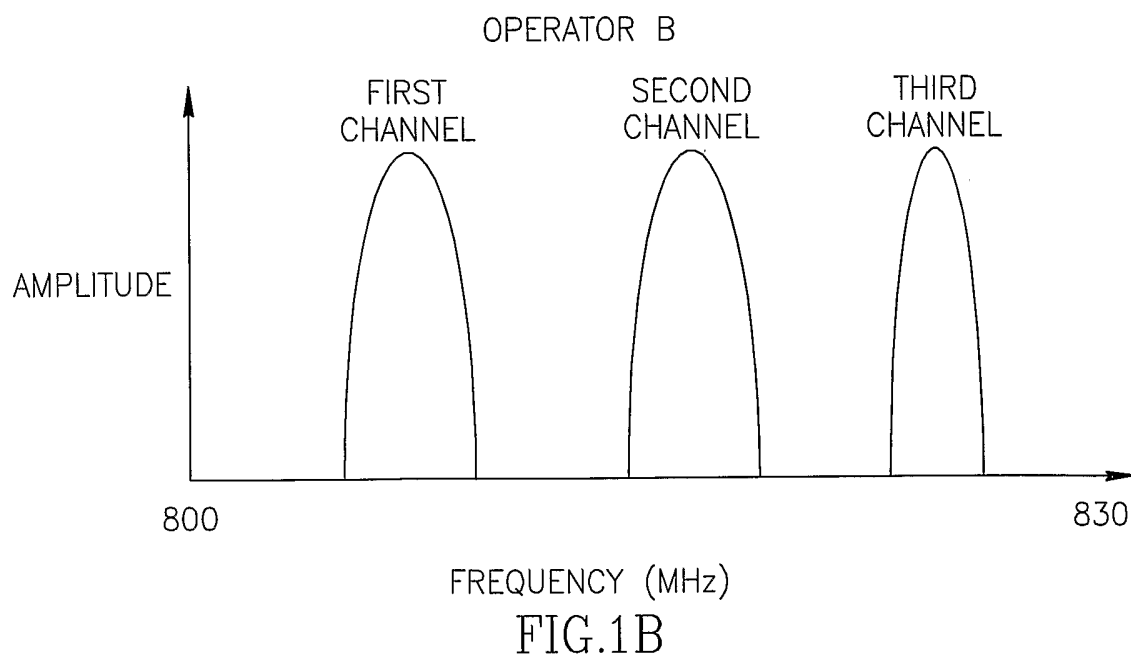
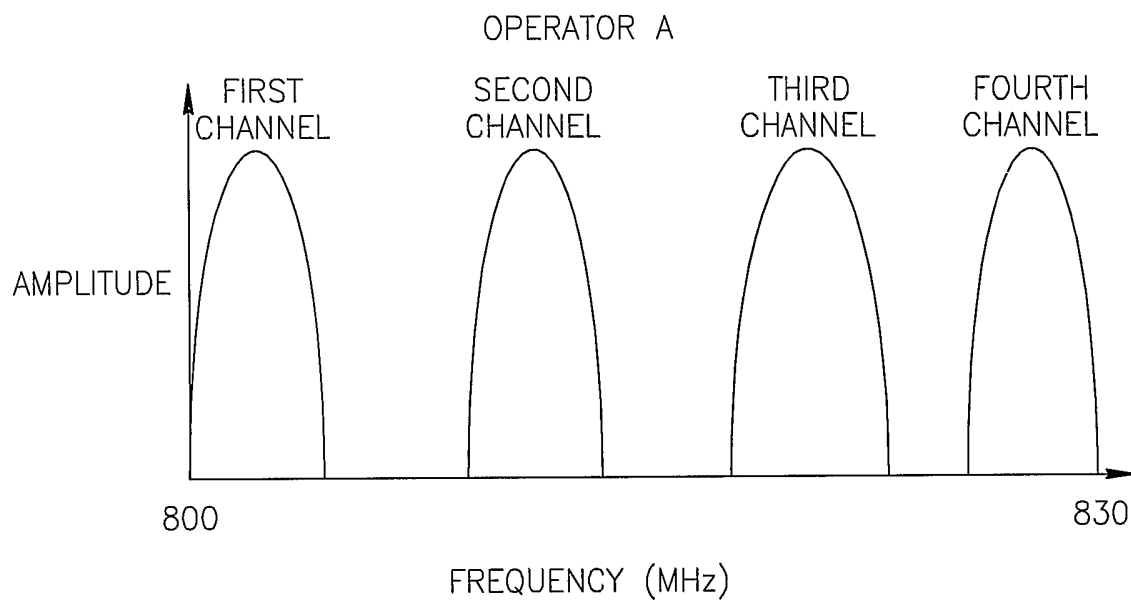
a transmitter to transmit the analog signal correlated to the filtered digital signal.

8. The system according to claim 7, further comprising a down converter to convert the received signal to an intermediate frequency.

9. The system according to claim 8, further comprising an up
5 converter to convert the analog signal correlated to the filtered digital signal to a transmission frequency.

10. The system according to claim 7, further comprising a
second digital filter configured to pass frequency components at or
10 around a second frequency associated with a second communication channel.

11. The system according to claim 10, further comprising a
summing unit to combine outputs from said first and second digital
15 filters.

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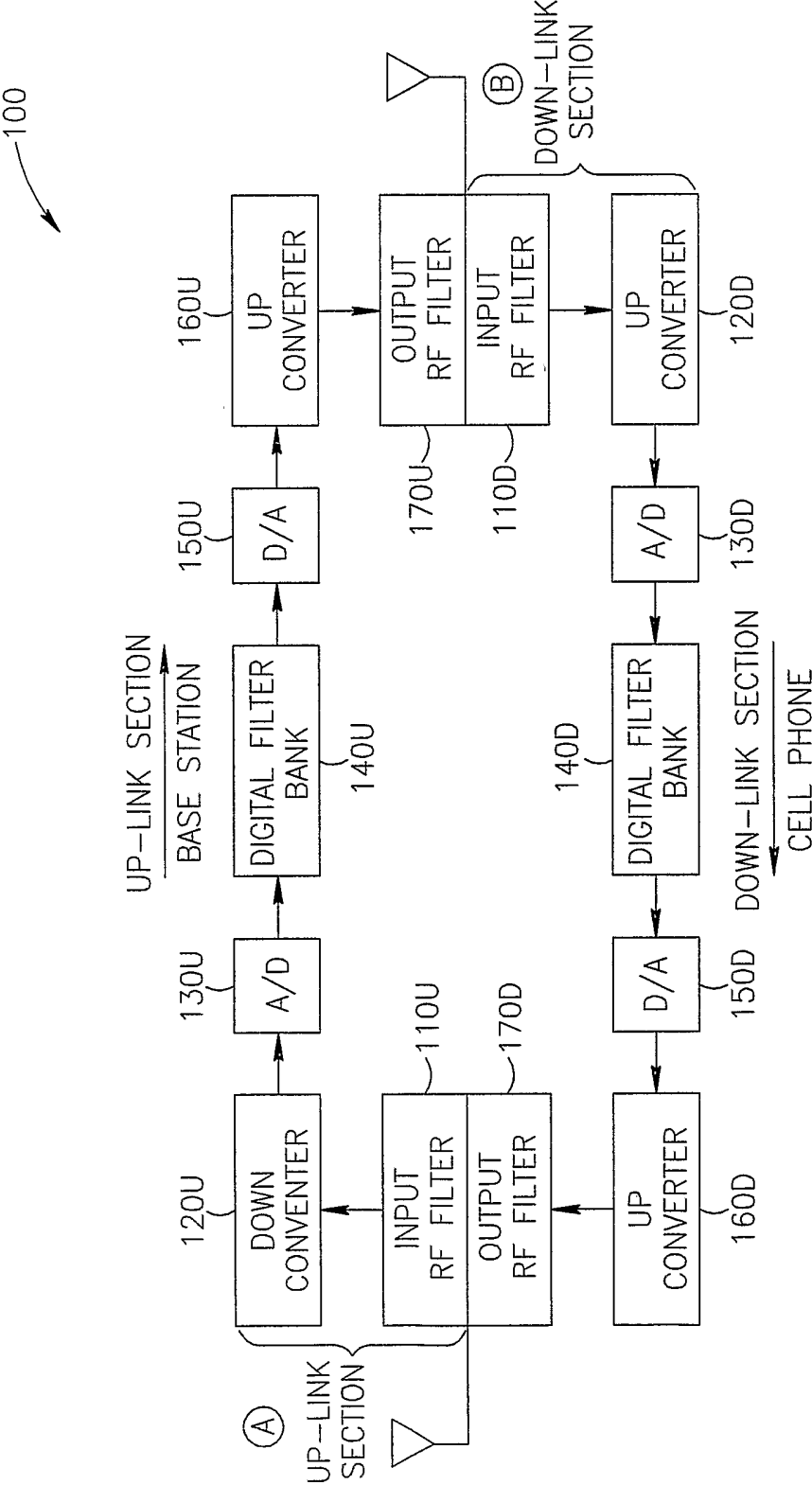


FIG.2

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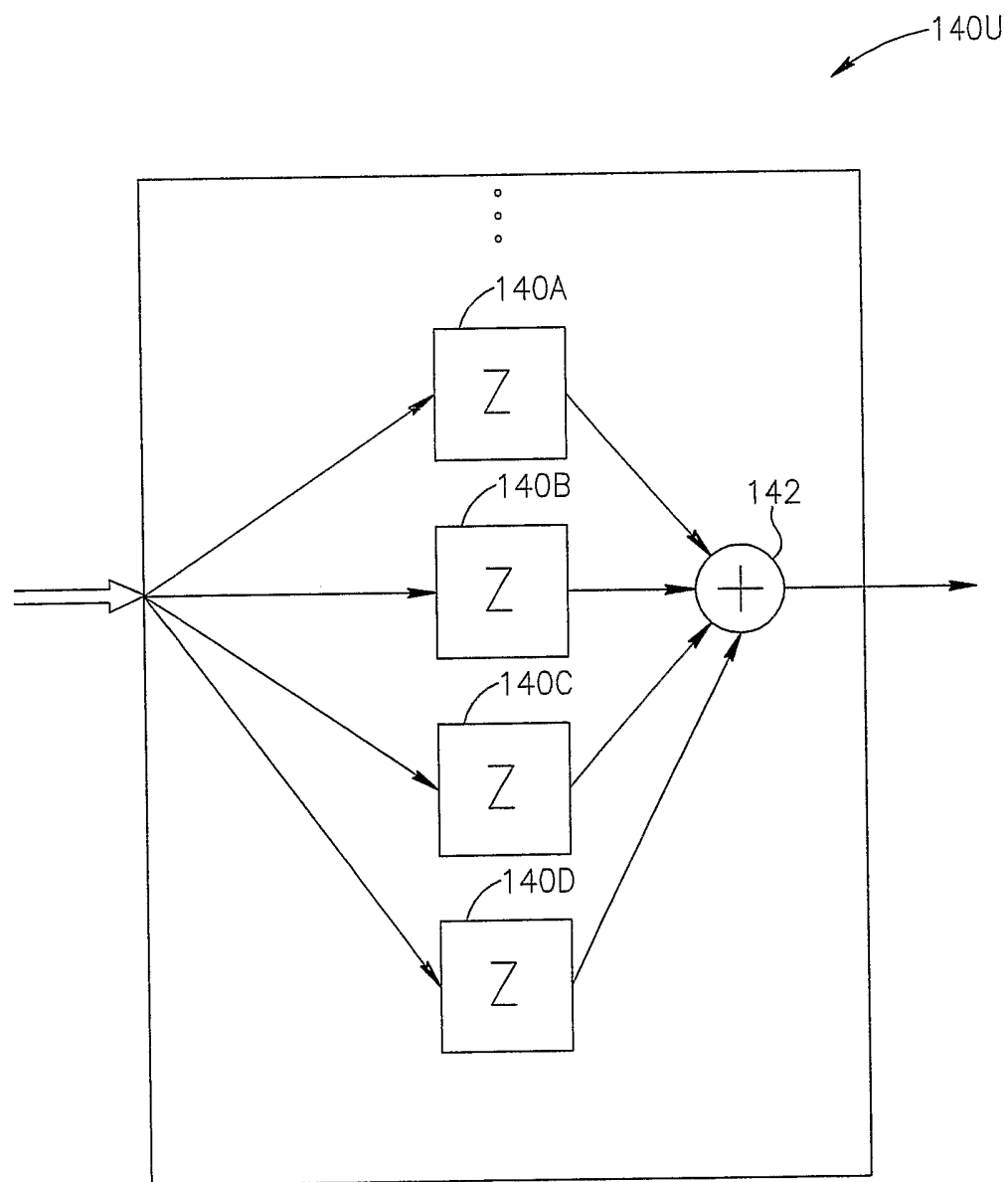


FIG.3

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FIG. 4A

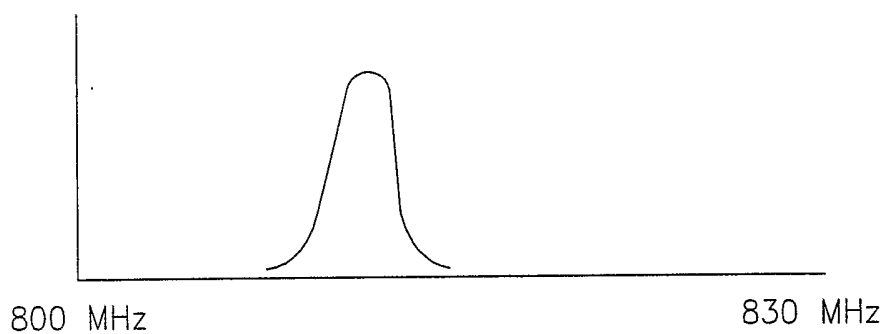


FIG. 4B

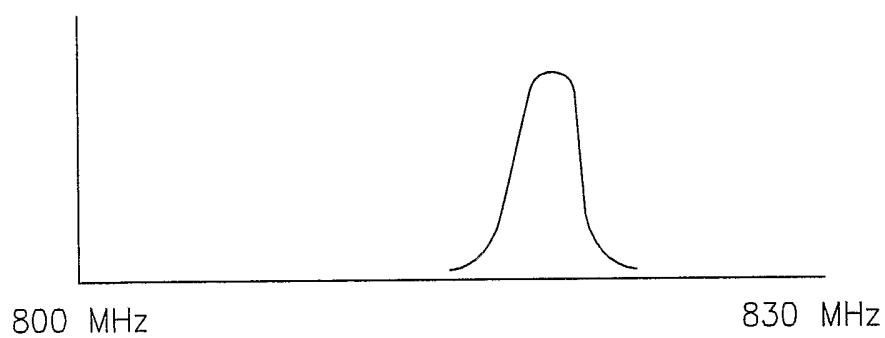


FIG. 4C

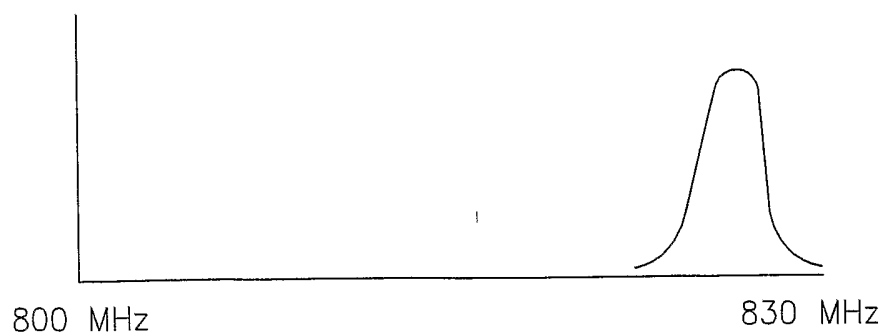


FIG. 4D

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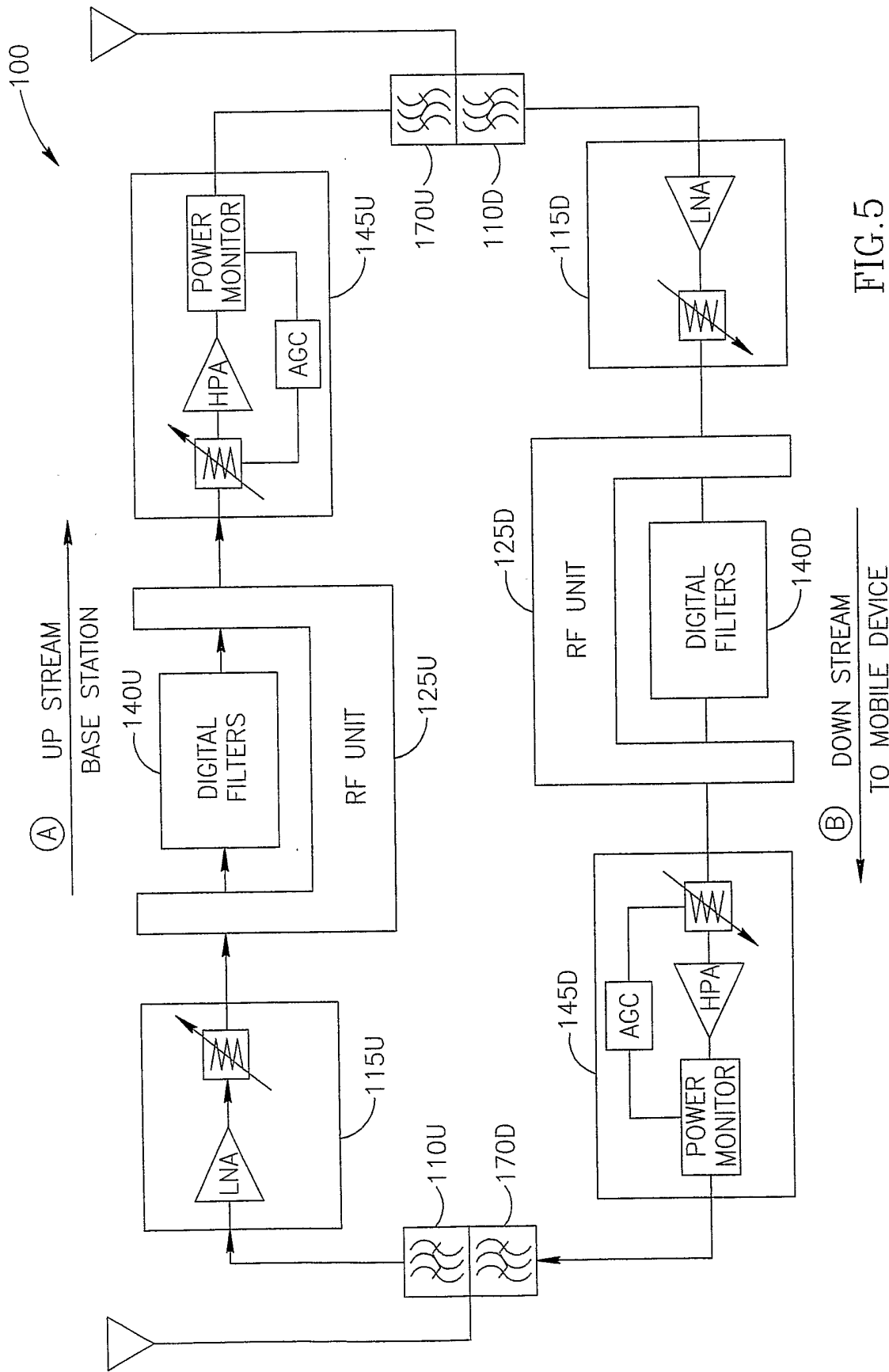


FIG.5