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CA 2412018 A1 2002/12/06

(21) 2 412 018

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2001/02/20
(87) Date publication PCT/PCT Publication Date: 2002/12/06
(85) Entrée phase nationale/National Entry: 2002/12/06
(86) N° demande PCT/PCT Application No.: CN 2001/000133
(87) N° publication PCT/PCT Publication No.: 2002/001776
(30) Priorité/Priority: 2000/06/12 (00108079.2) CN

(51) Cl.Int.^{7}/Int.Cl.^{7} H04J 13/00

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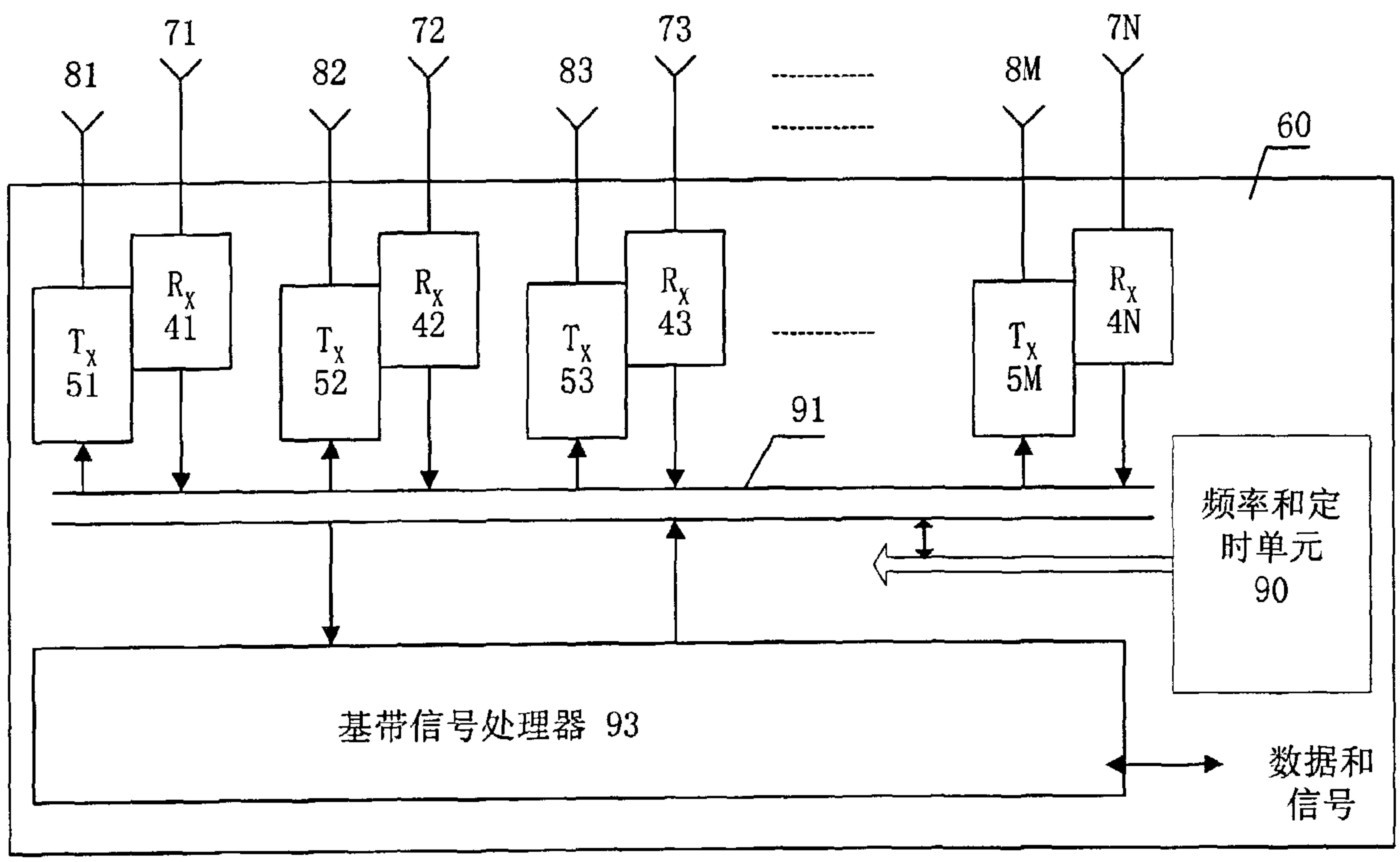
(54) Titre : PROCEDE ET APPAREIL UTILISANT UNE ANTENNE INTELLIGENTE DANS UN SYSTEME DE COMMUNICATION SANS FIL EN DUPLEX A DIVISION DE FREQUENCE
(54) Title: APPARATUS AND METHOD USING SMART ANTENNA IN FDD WIRELESS COMMUNICATION SYSTEM



(57) Abrégé/Abstract:
Present invention relates to an apparatus and a method using smart antenna in frequency division duplex code division multiple access communication system, for resolving a limitation of smart antenna use due to asymmetric propagation of uplink electric wave and downlink electric wave. Wirless base station has a smart antenna array for transmitting and receiving, a relevant RF transmitter and receiver, and a common baseband signals processor. The method of this invention is to determine main link direction by using a estimates of signal DOA (direction of arrival) obtained from a received signals; in downlink beamforming manner, synthesize a expectantly obtained transmitting beam shape based on the main direction. The system can obtain an advantage of smart antenna, thereby improving coverage of cell, increasing capacity and reducing cost.

CA 02412018 2002-12-06

Abstract

The invention relates to a method and an apparatus using smart antenna in frequency division duplex code division multiple access mobile communication system, for solving limitation of smart antenna use due to asymmetric propagation of uplink electric wave and downlink electric wave. In the wireless base station, there are transmitting smart antenna array and receiving smart antenna array and associated transmitters and receivers, respectively, and a common baseband signal processor. In the method, the main path direction is determined by signal direction of arrival, obtained from receiving signal; in the downlink beam forming, an expected transmitting beam form is based on the main path direction. The system can obtain advantages of smart antenna, improve cell coverage, increase system capacity and reduce cost.

APPARATUS AND METHOD USING SMART ANTENNA IN FDD WIRELESS COMMUNICATION SYSTEM

Field of the Technology

The present invention relates generally to Code Division Multiple Access (CDMA) cellular mobile communication system, and more particularly to a smart antenna technology applied in a Frequency Division Duplex (FDD) CDMA cellular mobile communication system.

Background of the Invention

Smart antenna is one of the most important technologies in modern wireless communication. Especially, when smart antenna technology is used in a CDMA cellular mobile communication system, there are advantages, such as increasing system capacity greatly, increasing cover range of a wireless base station, decreasing system cost and raising system performance etc. Therefore, smart antenna technology has become an important technology concerned all over the world.

At present, smart antenna technology is mainly used in time division duplex (TDD) CDMA wireless communication system including cellular mobile communication system, wireless subscriber loop and wireless local area network etc. The main reason is that in a TDD system, a transmitting channel and a receiving channel use same frequency, electric-wave propagation characteristics of uplink (receiving) and downlink (transmitting) are the same. Therefore, parameters of receiving signal beam forming obtained from uplink can be again used for downlink beam forming. Consequently, advantages of smart antenna are brought into full play.

Nevertheless, in present cellular mobile communication systems, FDD wireless communication system is the most popular one. In a FDD wireless communication system, uplink and downlink use different carrier frequencies, and electric-wave propagation characteristics of uplink and downlink are totally different. The result is that parameters of receiving signal beam forming obtained from uplink cannot be again used for downlink beam forming, so advantages of smart antenna cannot be brought into full play.

In a base station of FDD wireless communication system, when using smart antenna since receiving link and transmitting link work simultaneously with different frequency band, so one set or multiple sets of smart antenna array can be used for receiving and transmitting, respectively. Working method and principle of the receiving link smart antenna can refer to smart antenna technology used in a TDD wireless communication system, such as Chinese Patent ZL 97 1 04039.7 titled: "A time division duplex synchronous CDMA wireless communication system with smart antenna". However, the beam forming of transmitting downlink cannot simply use the parameters obtained from receiving uplink beam forming associated with every antenna unit. This is determined by unsymmetrical electric-wave propagation characteristics of uplink and downlink in a FDD wireless communication system.

Summary of the Invention

Purpose of the invention is to provide a method and apparatus for using smart antenna in a FDD wireless communication system. The method and apparatus can overcome the obstacle of using smart antenna in a FDD CDMA mobile communication system, which is caused by unsymmetrical electric-wave propagation characteristics of uplink and downlink. Accordingly, a FDD CDMA cellular mobile communication system using smart antenna can be implemented.

According to one aspect of the invention, a method for using smart antenna in a FDD wireless communication system is characterized to comprise the following steps:

a. Downlink radio frequency transmitting and uplink radio frequency receiving use independent smart antenna array, feeder cables and radio frequency transmitters or radio frequency receivers respectively, but use a common baseband signal processor;

b. Signal direction-of-arrival estimate values, obtained from uplink receiving signal, determines direction of the main path of the uplink receiving signal;

c. According to the main path direction, an expected downlink transmitting beam form is got.

What said signal direction-of-arrival estimate, obtained from uplink receiving signal, determines direction of main path further includes steps as fellow. N receiving signal preprocessors demodulate and de-spread N digital signals, coming from receiving antenna array and receivers. Receiving beam former makes direction-of-arrival estimate for each digital signal, respectively; makes combination algorithm for every digital signal to perform receiving beam forming and gets direction of the main path; sends the direction-of-arrival estimate value of the main path to downlink transmitting link. The combined digital signals are then recovered to original N receiving signals at a post-processor.

What said a signal direction-of-arrival estimate, obtained from uplink receiving signal, determines direction of main path is performed at the common baseband signal processor of a base station.

What said getting an expected obtaining downlink transmitting beam form according to the main path direction further includes steps as follow. A basic digital signal processor makes basic processing, including channel coding, interleaving, spread spectrum modulation and radio frequency modulation, for every digital signal which waits to be sent; and then sends to a transmitting beam former. The transmitting beam former makes transmitting antenna beam forming for each digital signal with reference to the direction-of-arrival estimate value of the main path, coming from the receiving beam former. For every transmitting link, digital combination is performed in a digital combiner, respectively, and the generated M digital signals are sent to individual transmitters and transmitting smart antenna array.

What said the transmitting beam former makes transmitting antenna beam forming for each digital signal with reference to the direction-of-arrival estimate value of main path, coming from a receiving beam former, is to add an amplitude and a phase value needed for transmitting beam forming for data which waits to be sent to transmitting smart antenna array.

Said to combine an expected downlink transmitting beam form according to the main path direction is performed in the common baseband signal processor.

A digital signal transmission is done by a radio frequency receiver through A/D converter or by a radio frequency transmitter through D/A converter, then through high-speed data bus to the common baseband digital signal processor.

Said downlink radio frequency smart antenna array and uplink radio frequency smart antenna array both can be one set or multiple sets.

Said downlink beam form can be a pencil beam.

Said combination manner of the downlink transmitting beam forming is determined by geometric structure of the transmitting smart antenna array.

According to another aspect of the invention, an apparatus for using smart antenna in a FDD wireless communication system includes a receiving antenna array and a transmitting antenna array constituted an antenna feed system, a radio frequency receiver connected with the receiving antenna array, a radio frequency transmitter connected with the transmitting antenna array and a common baseband signal processor; the radio frequency receiver and the radio frequency transmitter connected with the baseband signal processor through a data bus, and the radio frequency receiver and the radio frequency transmitter commonly using a frequency and timing unit.

Said receiving antenna array includes *N* receiving antenna units, connected with *N* radio frequency receivers through feeder cables, respectively. Said transmitting antenna array includes *M* transmitting antenna units, connected with *M* radio frequency transmitter through feeder cables, respectively. Wherein, *M* and *N* are an plus integer.

Said baseband signal processor is consisted of an uplink baseband signal processor and a downlink baseband signal processor. In the uplink beam forming, the uplink baseband signal processor sends the DOA estimate value of main path to the downlink baseband signal processor for downlink beam forming.

Said uplink baseband signal processor includes *N* receiving signal preprocessors which demodulates and de-spreads *N* digital signals coming from receiving antenna array and receivers; a receiving beam former which makes DOA estimate for *N* digital signals, coming from *N* receiving signal preprocessors, respectively, and combines the *N* digital signals; and a post-processor which recovers the combined digital signal to the original *N* receiving digital signals. Said downlink baseband signal processor includes a basic digital signal processor which makes some basic processing for each digital signal waiting to be transmitted; a transmitting beam former which makes transmitting antenna beam forming for each digital signal outputted from the basic digital signal processor with reference to the DOA estimate value of main path coming from the receiving beam former; and a digital combiner which performs digital combination for every transmitting link to form M digital signals which is sent to the M transmitters and the transmitting antenna array with M antenna units.

In the invention, in a base station of a FDD CDMA mobile communication system, the radio frequency receiving and radio frequency transmitting individually use a smart antenna array. The antenna units, which constitute the smart antenna array, and associated feeder cables are connected to corresponding radio frequency transmitters or radio frequency receivers, respectively; then to a common baseband signal processor through ADC and DAC, respectively.

In the invention, the direction of main path is determined by using signal DOA estimate values obtained from receiving signals. Then, according to this main path direction, an expected transmitting beam form, for example a pencil beam, is got. The method of downlink beam forming is determined by a geometric structure of the transmitting antenna array, and is well-known in antenna array theory.

According to the method of the invention, in a FDD wireless communication system, a base station can totally obtain the smart antenna functions and characteristics in the uplink; and in the downlink, it is also implemented the smart antenna main functions, including decreasing interference and increasing equivalent transmitting power.

In the invention, for uplink any signal combination manner of a smart antenna can be used to bring fully the advantages of smart antenna into play. For downlink, especially in a mobile environment, the basic advantages of a smart antenna can be obtained; in addition, there is no strict relationship between downlink beam forming and a subscriber terminal position, and this has more advantages for a subscriber terminal working in a high-speed moving environment.

The method and basic station apparatus of the invention can overcome the limitation and obstacles of applying smart antenna technology in a FDD CDMA mobile communication system, the limitation and obstacles are caused by that electric wave propagation at uplink and downlink is unsymmetrical. At the same time, cell coverage is improved, system capacity is increased greatly and cost is reduced.

Comparing the smart antenna of the invention in a FDD wireless communication system and the smart antenna in a TDD wireless communication system, although it is impossible to combine the multipath signals during downlink beam forming in a FDD wireless communication system, and it is lost advantage of combining multipath signals within a code chip width by using time delay; but it is just because of having not considering the multipath signals combination in a downlink beam forming, the downlink beam forming is not sensitive to phase (time) and is very suitable for high-speed moving terminal. In this way, problem of applying smart antenna technology in a high-speed moving environment is solved.

Experiments show that when applying smart antenna with the method and apparatus of the invention in a base station of a FDD CDMA mobile communication system, the system will improve cell coverage, increase capacity, reduce cost and support working at high-speed moving environment.

Brief Description of the Drawings

Fig.1 shows a base station block diagram of a TDD wireless communication system with smart antenna.

Fig.2 shows a base station block diagram of a FDD wireless communication system with smart antenna.

Fig.3 shows a block diagram of a baseband signal processor and its signal processing in a base station for a FDD wireless communication system with smart antenna.

Fig.4 shows a beam-forming diagram, including Figures 4A, 4B and 4C, for a FDD smart antenna system of the invention.

Embodiments of the Invention

The invention will be further described in the following, with reference to drawings and embodiments.

The invention is a method and an apparatus for using smart antenna in a FDD CDMA wireless communication system. In the following, technical scheme and technical advantage of the invention will be described in detail by taking a FDD CDMA wireless communication system, such as a CDMA FDD system of IMT-2000, as an example.

Fig.1 shows a block diagram of a wireless base station 10 for a TDD wireless communication system with smart antenna. The base station works in a CDMA TDD mode. The antenna feed system of the base station is consisted of an antenna array, consisted of *N* antenna units 11, 12, 13, ..., 1N, and associated feeder cables, i.e. *N* antenna feeder cables. The *N* antenna feeder cables are correspondingly connected to *N* radio frequency transceivers TRx 21, 22, 23, ..., 2N, respectively. The radio frequency transceivers commonly use a local oscillation source (frequency and timing unit) 30, i.e. the *N* radio frequency transceivers TRx work coherently.

A received signal of each radio frequency transceiver is converted to a digital sampled signal through the inner analog digital converter (ADC). The digital sampled signal is sent to the high-speed data bus 31. A digital signal, waiting to be sent, on the high-speed data bus 31 is sent to a corresponding radio frequency transceiver TRx, and is converted to a analog signal through the inner digital analog converter (DAC). The analog signal is then transmitted through a corresponding antenna feed unit.

All baseband digital signal processing is performed in the baseband digital signal processor 33. Methods of the baseband digital signal processing can refer to related patents, such as Chinese Patent ZL 97 1 04039.7. With the present advanced digital signal processing (DSP) technology, the baseband digital signal processor 33 can implement functions, such as signal modulation and demodulation, receiving and transmitting beam forming etc., overcome multi-address and multipath interference, raise receiving signal to noise ratio and sensitivity and increase equivalent isotropically radiate power (EIRP). One set of antenna feed system, in a TDD wireless communication system base station with smart antenna, is simultaneously used for receiving and transmitting (TRx).

The description of Fig.1 above is also the principle and concept of modern smart antenna.

Fig.2 shows a block diagram of a wireless base station 60 of the invention for a FDD wireless communication system with smart antenna. The base station works in a CDMA FDD mode. The antenna feed system of the base station includes two antenna arrays: receiving antenna array and transmitting antenna array. The receiving antenna array (uplink) includes *N* receiving antenna units 71, 72, 73, ..., 7N and associated feeder cables, i.e. it is consisted of *N* receiving antenna feed units. The *N* receiving antenna feed units are connected with *N* radio frequency receivers (Rx) 41, 42, 43, ..., 4N, respectively. The transmitting antenna array (downlink) includes *M* transmitting antenna units 81, 82, 83, ..., 8N and associated feeder cables, i.e. it is consisted of *M* transmitting antenna feed units. The *M* transmitting antenna feed units are connected with *M* radio frequency transmitters (Tx) 51, 52, 53, ..., 5M, respectively. The radio frequency receivers and transmitters commonly use a local oscillation source (frequency and timing unit) 90, i.e. the *N* radio frequency receivers and *M* radio frequency transmitters work coherently.

For uplink, a received signal of each radio frequency receiver (Rx) is converted to a digital sampled signal through the inner ADC, and then the digital sampled signal is sent to the high-speed data bus 91. In the wireless base station 60, baseband digital signal processing of the signals, coming from respective radio frequency receiving link, is performed in the baseband digital signal processor 93. The baseband digital signal processing includes demodulation, de-spread spectrum, overcoming various interference, obtaining DOA estimate and receiving beam forming, etc. The method of the digital signal processing is same as the beam forming method of smart antenna in TDD wireless communication system. This can refer to the applicant Chinese Patent ZL 97 1 04039.7, titled "Time Division Duplex synchronization CDMA wireless communication system with smart antenna", and other correlative patents.

For downlink, a digital signal, waiting to be transmitted, is firstly processed with the basic digital signal processing, including channel allocation, channel coding, interleaving, I/Q (in phase/ quadrature phase) separation, modulation and spread spectrum etc., in the baseband digital signal processor 93; then a downlink beam forming is made. The downlink beam forming is based on the DOA estimates obtained from the uplink baseband digital signal processing. Means for downlink beam forming can use well-known algorithms in antenna array theory. During downlink beam forming, digital signals to be sent to each transmitting link are added with a phase and amplitude value needed for beam forming; then through digital combination of multiple code channel signals, a digital signal, waiting to be transmitted, for each transmitting link is formed. The digital signal, waiting to be transmitted, is sent to a corresponding radio frequency transmitter (Tx) through high-speed data bus 91, respectively; after converted by the inner DAC, it will be an analog signal and will be transmitted through a corresponding transmitting antenna unit.

Fig.2 shows an apparatus of the invention, which uses the uplink and downlink beam forming manner of the invention. Therefore, a wireless base station with smart antenna is implemented in a FDD wireless communication system.

In Fig.3, taking a FDD CDMA wireless communication system as an example, a baseband digital signal processor and signal processing procedure are described in detail.

In the uplink baseband digital signal processor, *N* line digital signals 101, 102, 103, ..., 10N, coming from receiving antenna array and receiver, firstly enter the corresponding *N* receiving signal preprocessors 111, 112, 113, ..., 11N, for demodulation and de-spread spectrum, respectively. Then, the signals enter receiving beam former 150 to make DOA estimates for each digital signals coming from subscriber terminal, respectively, and to combine signals coming from every receiving antenna with a certain algorithm, i.e. making receiving beam forming. The combined signal is recovered to the original receiving digital signals at the post-processor 155.

In the downlink baseband digital signal processor, each digital signal, waiting to be transmitted, has been made some basic processing in the digital signal processor 145, then is sent to the transmitting beam former 140. The transmitting beam former 140 makes transmitting antenna beam forming for each digital signal with reference to the DOA estimates 160 coming from the receiving beam former 150. This means adding a needed amplitude value and phase value to each transmitting antenna data, which will be sent to each transmitting antenna soon. After that, for each transmitting link, signal is combined at digital combiner 131, 132, 133, ..., 13M to form *M* line digital signals 121, 122, 123, ..., 12M to be sent to each corresponding transmitting link.

In Fig.3, receiving beam former 150, post-processor 155, transmitting beam former 140 and digital signal processor 145 can be multiple physical units in an implementation (number of units relates to complexity of each unit). In Fig.3, there are three overlap blocks to represent the multiple units.

Fig.s 4A to 4C show an embodiment of a wireless base station with smart antenna of the invention for a FDD CDMA mobile communication system.

Fig.s 4A to 4C show a typical mobile communication environment of a suburban area. In these Fig.s, there are two wireless base stations 200 and 201 and one subscriber terminal 210, and rectangular blocks represent buildings. The uplink signal between the wireless base station 200 and the subscriber terminal 210 includes the main path signal 220 and many multipath signal 221, 222, 223, ... etc., caused by building reflection etc. Along with different environment, amplitude and time delay of each multipath signal are different. Suppose the time delay of the multipath signals 221 and 222 is within one code chip width, and time delay of other multipath signals excesses one code chip width. After using method and apparatus of the invention, the receiving antenna array 230 of the wireless base station 200 obtains a uplink receiving beam form, shown in Fig. 4B with 232, which uses energy of the main path and short time delay multipath effectively. As shown in Fig. 4C, the beam 242 (downlink beam) transmitted by transmitting antenna array 240 of the wireless base station 200 is formed according to the DOA estimates of uplink receiving beam. The downlink beam is only pointed to direction of the uplink main path 220. The downlink transmitting beam is a pencil form beam.

In general, since a subscriber terminal applies an isotopic antenna for receiving, the downlink beam, shown in Fig. 4C, has multipath components, generated during electric wave propagation because of reflection etc. Therefore, in a subscriber terminal when processing baseband digital signal, it is wanted to overcome interference of these multipath components.

Obviously, the method and apparatus of the invention, after updated appropriately, can be used in other mode of a wireless communication system.

Claims

1. A method for using smart antenna in a frequency division duplex (FDD) wireless communication system, comprising:

A. using independent smart antenna array, feeder cables, radio frequency transmitters/radio frequency receivers, but a common baseband signal processor in downlink radio frequency transmitting and uplink radio frequency receiving, respectively;

B. getting estimate values of signal direction-of-arrival (DOA) from a uplink receiving signal, and determining direction of the main path of the uplink receiving signal;

C. getting an expected downlink transmitting beam form according to the main path direction.

2. The method according to Claim1, wherein the step B further comprises the steps of:

demodulating and de-spreading *N* digital signals of a uplink receiving signal, coming from the receiving smart antenna array and the radio frequency receivers by *N* receiving signal preprocessors;

making DOA estimate for each digital signal by a receiving beam former, respectively;

combining every digital signal to perform receiving beam forming, and getting direction of the main path of the uplink receiving signal;

sending the DOA estimate value of the main path to downlink transmitting link, and recovering the combined digital signal to original *N* receiving digital signals in a post-processor.

3. The method according to Claim2, wherein the step B is performed in the common baseband signal processor of a base station.

4. The method according to Claim1, wherein the step C further comprises the steps of:

making basic processing, including channel coding, interleaving, spread spectrum modulation and radio frequency modulation, for each digital signal, which is waiting to be sent, by a basic digital signal processor, and then sending the processed digital signals to the transmitting beam former;

making transmitting antenna beam forming by a transmitting beam former for each digital signal with reference to the DOA estimate value of the main path, coming from the receiving beam former;

digitally combining each transmitting link in a digital combiner, respectively, to generate M digital signals, and then sending the M digital signals to individual transmitters and transmitting smart antenna array.

5. The method according to Claim4, wherein making transmitting antenna beam forming is to add an amplitude and a phase value needed for transmitting beam forming for data which is waiting to be sent to the transmitting smart antenna array.

6. The method according to Claim4 or Claim5, wherein the step B is performed in the common baseband signal processor of a base station.

7. The method according to Claim1, further comprises:

digital signal transmission is done by the radio frequency receiver through A/D converter or by a radio frequency transmitter through D/A converter, then through a high-speed data bus to the common baseband digital signal processor.

8. The method according to Claim1, wherein the smart antenna array of downlink radio frequency transmitting or the smart antenna array of uplink radio frequency receiving is one set or multiple sets.

9. The method according to Claim1, wherein the downlink transmitting beam form is a pencil beam.

10. The method according to Claim1, wherein in step C, the method of getting an expected downlink transmitting beam form is determined by geometric structure of the transmitting smart antenna array.

11. An apparatus for using smart antenna in a frequency division duplex (FDD) wireless communication system, comprising:

an antenna feed system consisted of a receiving antenna array and a transmitting antenna array;

a radio frequency receiver connected with the receiving antenna array;

a radio frequency transmitter connected with the transmitting antenna array, and

a common baseband signal processor;

wherein the radio frequency receiver and the radio frequency transmitter are connected with the baseband signal processor through a data bus, and the radio frequency receiver and the radio frequency transmitter commonly use a frequency and timing unit.

12. The apparatus according to Claim11, wherein the receiving antenna array comprises *N* receiving antenna units, which are correspondingly connected with *N* radio frequency receivers through feeder cables, respectively; the transmitting antenna array comprises *M* transmitting antenna units, which are correspondingly connected with *M* radio frequency transmitter through feeder cables, respectively; wherein, *M* and *N* are an plus integer.

13. The apparatus according to Claim11 or Claim12, wherein the baseband signal processor is consisted of an uplink baseband signal processor and a downlink baseband signal processor; in the uplink beam forming, the uplink baseband signal processor sends DOA estimate values of main path to the downlink baseband signal processor for downlink beam forming.

14. The apparatus according to Claim13, wherein the uplink baseband signal processor comprises:

N receiving signal preprocessors, which demodulate and de-spread spectrum the *N* digital signals coming from the receiving antenna array and receivers;

a receiving beam former, which makes DOA estimate for *N* digital signals, coming from *N* receiving signal preprocessors, and combines the *N* digital signals; and

a post-processor, which recovers the combined digital signal to original *N* receiving digital signals.

15. The apparatus according to Claim13, wherein the downlink baseband signal processor comprises:

a basic digital signal processor, which makes basic processing for each digital signal waiting to be transmitted;

a transmitting beam former, which makes transmitting antenna beam forming for each digital signal outputted from the basic digital signal processor with reference to the DOA estimate value of the main path coming from the receiving beam former; and

a digital combiner, which performs digital combination for every transmitting link to form *M* digital signals which will be sent to the *M* transmitters and transmitting antenna array.

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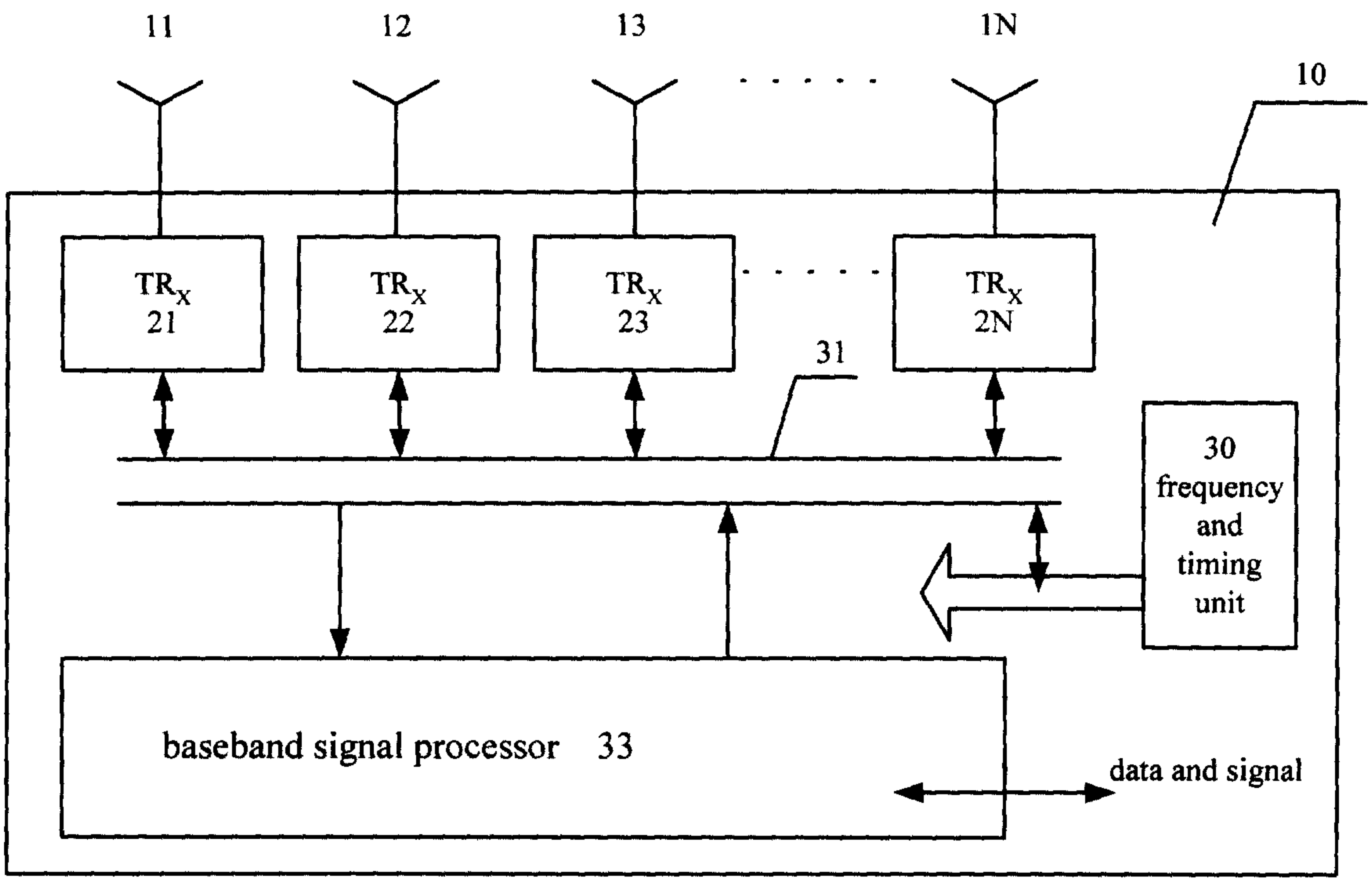
11
12
13
1N
10
TRX 21
TRX 22
TRX 23
TRX 2N
31
30 frequency and timing unit
baseband signal processor 33
data and signal

FIG. 1

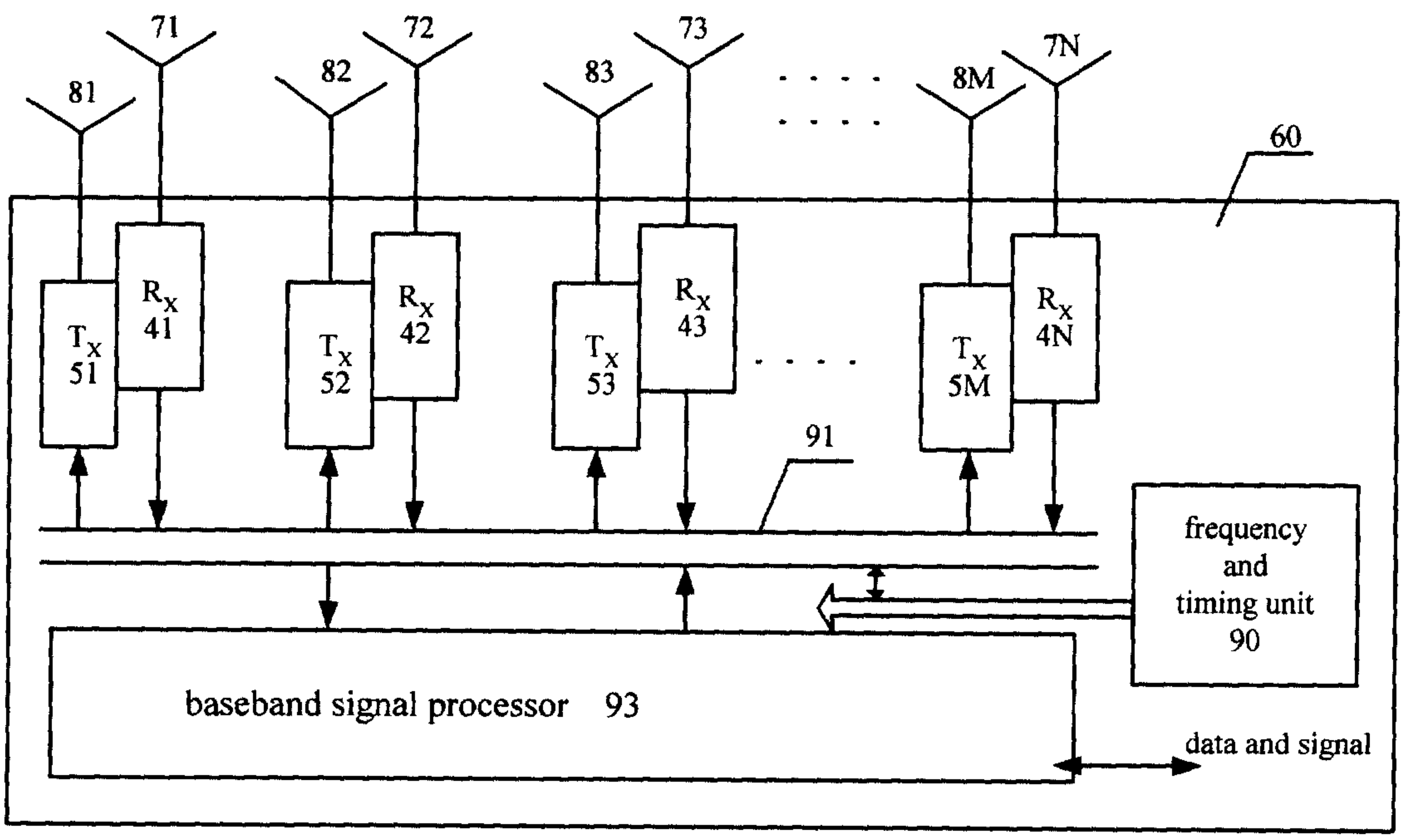
71
72
73
7N
81
82
83
8M
60
TX 51
RX 41
TX 52
RX 42
TX 53
RX 43
TX 5M
RX 4N
91
frequency and timing unit 90
baseband signal processor 93
data and signal

FIG. 2

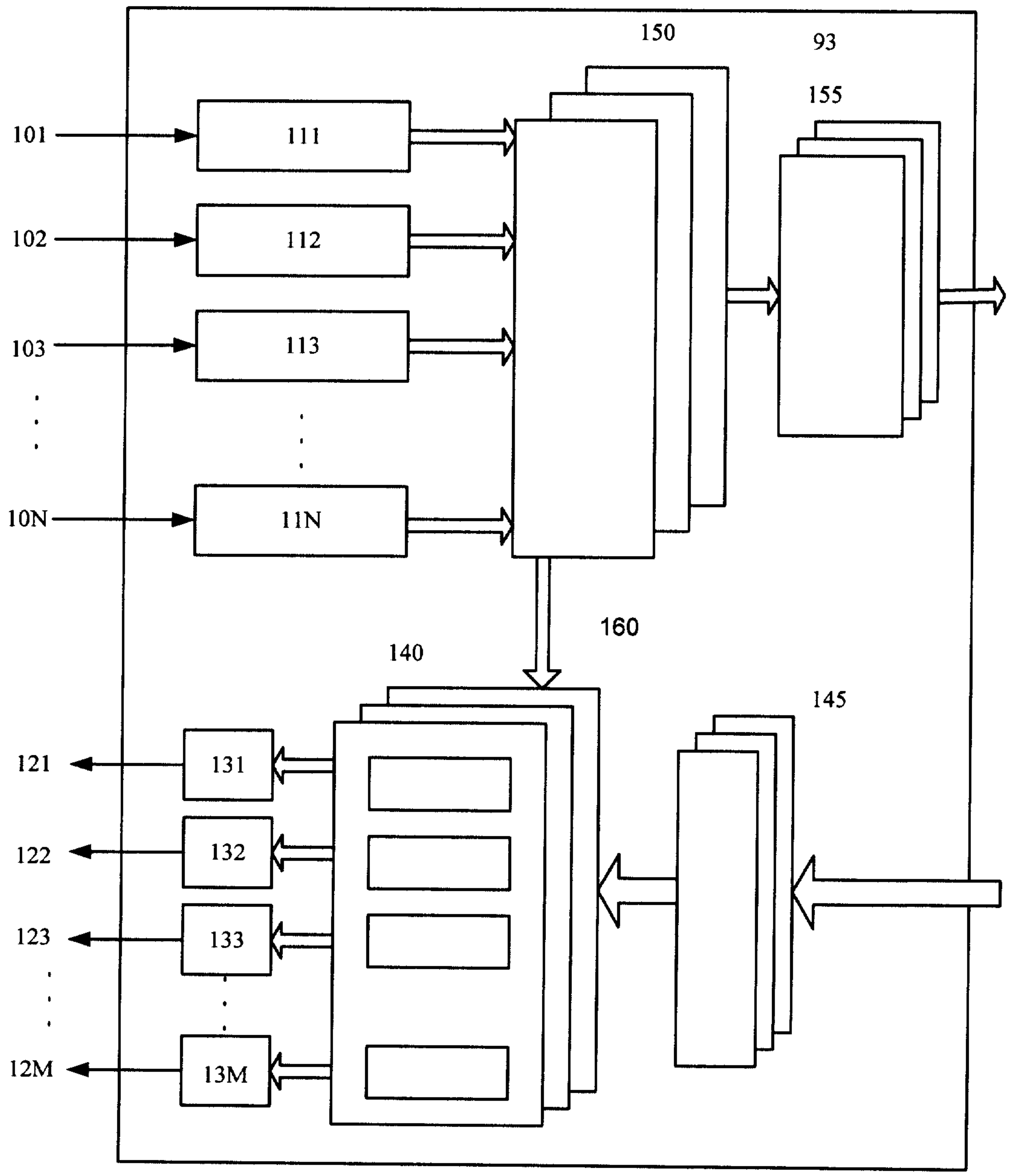
150
93
155
101
111
102
112
103
113
10N
11N
160
140
145
121
131
122
132
123
133
12M
13M

FIG. 3

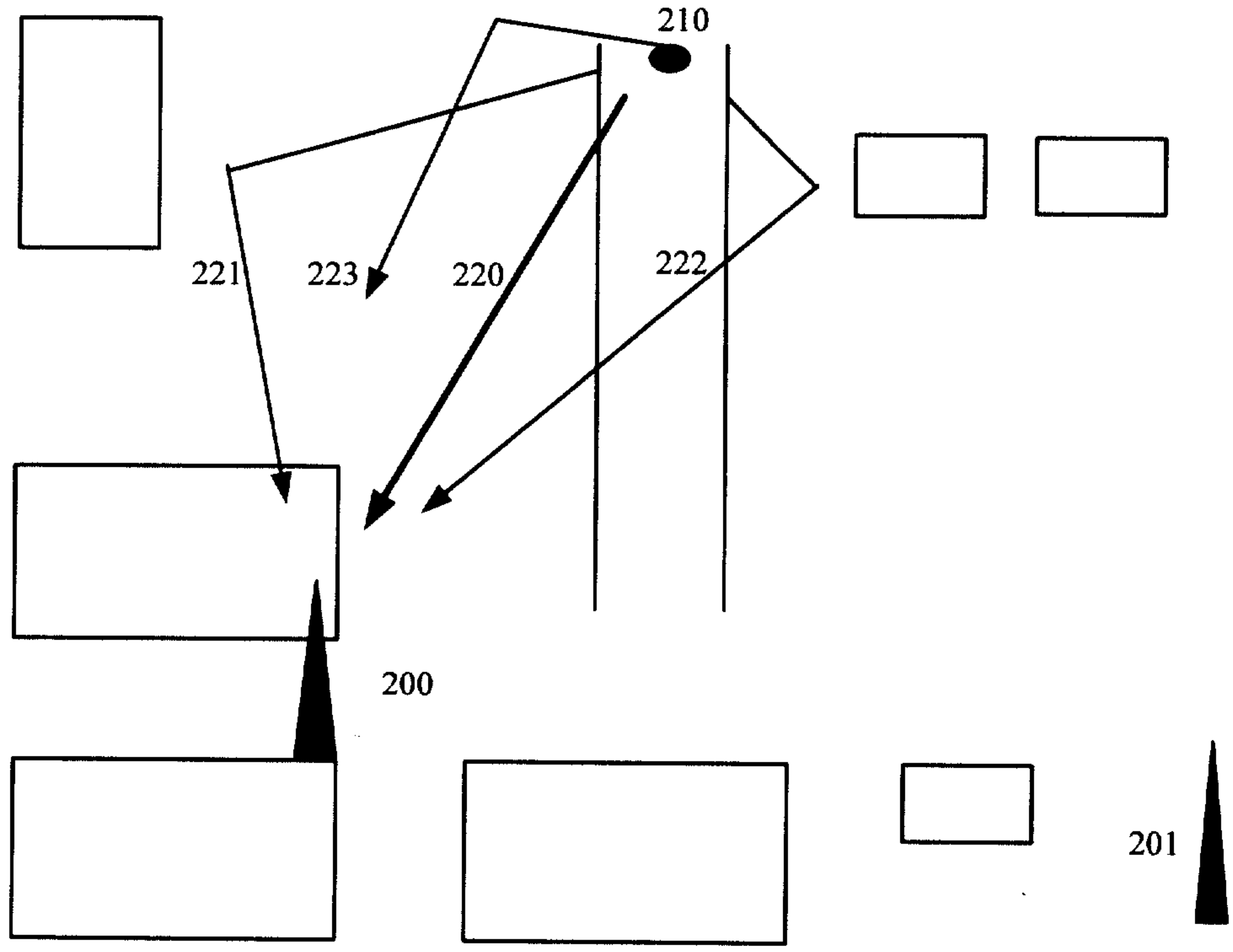

FIG. 4A

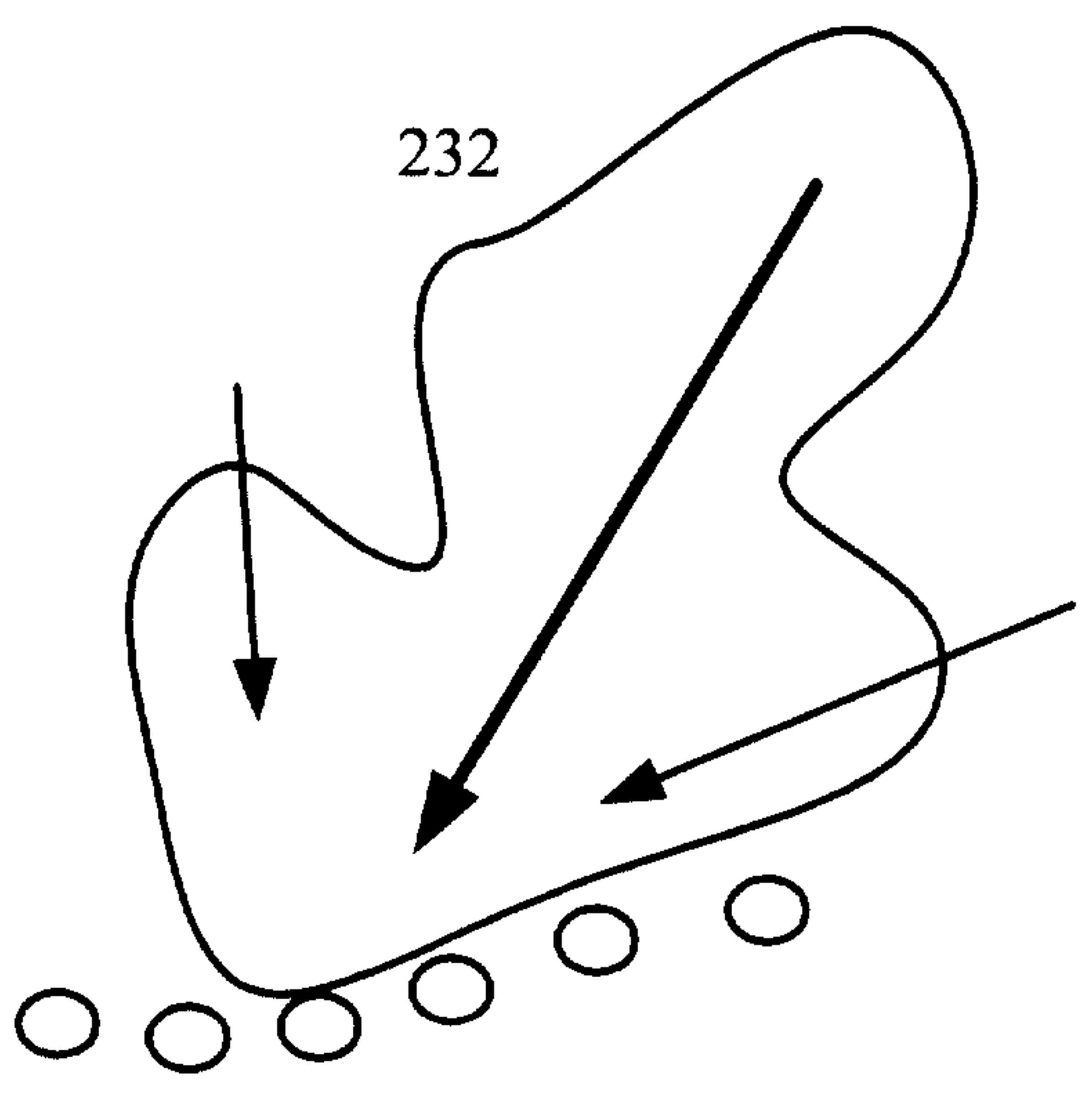

FIG. 4B

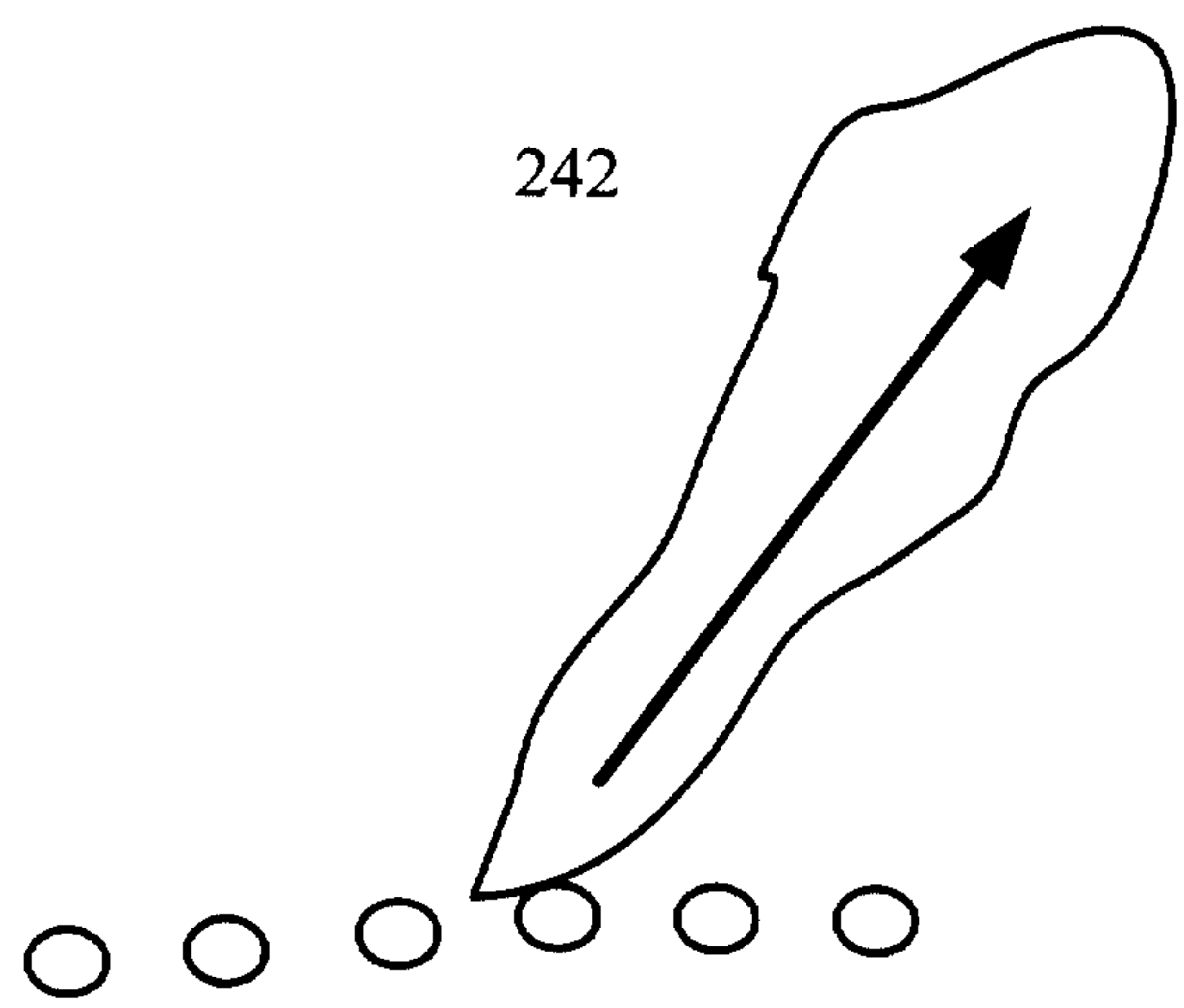

FIG. 4C


71
72
73
7N
81
82
83
8M
60
R_X 41
R_X 42
R_X 43
R_X 4N
T_X 51
T_X 52
T_X 53
T_X 5M
91
频率和定时单元 90
基带信号处理器 93
数据和信号