Description

(1) Field of the Invention

This invention relates generally to a portable radio telephone system. More particularly, the present invention relates to a private radio telephone system, for use in a local area such as in a office building or in a factory, of the type wherein when its portable telephone set is taken out from the area, it can communicate with subscribers of public telephone network through a public cellular radio telephone system which has already been in service over urban areas.

(2) Description of the Prior Art

A public cellular radio telephone system has been known in the past as a urban cellular radio telephone system. When its portable telephone set is brought into an office building or in a factory and connected to a subscriber of the private branch exchange for communication, not only the quality of telephone voice drops due to radio wave propagation attenuation by the office building but also the telephone charge of the urban cellular telephone system must be paid.

As one of the prior art references of urban cellular radio telephone systems which improve the radio wave propagation attenuation of this kind, can be seen in Proceedings of IEEE-VT Conference, 1984, pp 162.

In the portable telephone system described in the prior art reference mentioned above, introduction of a private branch exchange which has radio telephone subscriber circuits is not taken into consideration, so that direct communication cannot be made from the portable telephone set to the subscribers of the private branch telephone system.

On the other hand, if we introduce private branch radio telephone systems that have been commonly considered, the portable telephone set becomes expensive because it must have a radio frequency circuit of the private radio frequency channels in addition to the radio frequency of the urban cellular radio telephone.

US-A-4 144 411 discloses a cellular radio telephone system for flexible use of different cell sizes. According to this document all radio communication is carried out by use of radio waves of public cellular radio telephone systems.

SUMMARY OF THE INVENTION

The object of the present invention is to accomplish a portable radio telephone system wherein a portable telephone set can be used both for an urban public cellular radio telephone system and for a private radio telephone system which is built inside a local area. For example, the present invention is directed to accomplish a portable radio telephone system wherein direct access can be made from a portable telephone set to the radio frequency circuit of a private branch exchange without causing any radio wave interference to a heretofore known urban cellular radio telephone system.

To realize the present invention, a portable radio telephone system of the type wherein a given area is divided into a plularity of large areas, each of the large areas is further divided into a plularity of small cellular areas, wherein the reuse of the same frequency channel is permitted between the large areas, different frequency channels are allocated to the small cellular areas of each large area and public radio communications made by portable telephone sets by use of the radio waves of the frequency channels allocated to the small cellular areas, the object of the present invention described above can be accomplished by a private radio telephone system consisting of an antenna for transmitting and receiving a radio wave pair which double reuse the same frequency channel pair with the public cellular radio telephone system but do not use the frequency channels allocated to the small cellular area wherein the private telephone system exits, a private branch exchange and a transceiver both of which are connected to the antenna and private radio communication is made through private branch exchange by use of the portable telephone sets.

Incidently, the power intensity of the radio wave radiated from the antenna is kept to a very low intensity level so that it does not affect the public cellular radio telephone system in the large areas, and also the frequency channel pair is selected so that they hardly interfere the public cellular radio telephone system or the large areas. To prevent the occurence of the wave interference, the antenna described above may have directivity.

When the portable radio telephone system of the present invention is disposed in a district where the density of subscribers of a public cellular radio telephone system is high, the radious of the small cellular area (cell or sector) becomes little so that the service area of a local private system using a single antenna becomes narrow. In such a case, the local area is divided into a plularity of mini cells with each antenna and radio waves of different frequency channel pairs are reused among the mini cells to secure a required service area, as described, for example, in "Personal Communication", September, 1985, pp. 28.

The above and other objects and also novel features of the present invention will become more apparent from the following description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1, 4, 6 and 7 show examples of cell disposition of a urban cellular radio telephone system of the present invention;

Fig. 2 is an explanatory view of the intensity of a radio wave in an embodiment or the present invention;

Figs. 3 and 5 are schematic views showing the construction of the portable radio telephone system of the present invention;

Fig. 8 is a block diagram showing the construction of a portable telephone set used for the portable radio telephone system in one embodiment of the present invention; and

Fig. 9 shows the output power levels at which the portable telephone set of Fig. 8 operates.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig. 1 shows an example of cell disposition of a heretofore known public cellular radio telephone system in order to have the present invention more easily understood.

A given area is divided into a plurality of large areas (which are referred to as "cluster") represented by thick lines and each of the clusters is divided into twelve cells (small areas) 1 - 12. An antenna for transmission and reception (represented by black dot ".") is disposed at the center of each cell.

Radio frequency channels are allocated to each cell in the number corresponding to the traffic of the radio telephone. These radio waves will be called "f_1" in the cell 1, "f_2" in the cell 2, "f_3" in the cell 3, and so forth. The radio waves f_1, f_2, ... have an allocated bandwidth, and a plurality of frequency channels exist in each bandwidth related to the radio telephone traffic. Additionally, the position of the cell 1 in the cluster 13 is selected so that the intensity of the f_1 wave interference from outside the cluster becomes minimal.

In the portable radio telephone system of the present invention, radio communication is made between a private branch radio telephone system in one cell and a portable telephone set by use of frequencies different from the frequencies allocated to the cell.

Incidentally, the frequency and intensity of the radio waves used for the private branch radio telephone system are selected in the following manner least radio wave interference occurs with the other cells in the cluster. Namely, the frequency channels allocated to the cell 1 must be the channels which are used in the most apart from the cell 1. Thus, the f_2 wave of the cell 2 exists for the cell 1. The cell 4 is the most remote from the cell 1 inside the cluster 13, but the interference intensity of the f_4 wave from outside the cluster 13 is greater than that of the f_2 wave. The f_3 wave used in the cell 3 also satisfies the condition described above.

Fig. 2 shows the intensity of radio wave used by the portable radio telephone system of the present invention. In other words, when the private radio telephone system O of the present invention is disposed inside the cell 1 as is shown in Fig. 1, the electric field intensity E_1 of the radio wave radiated from the cell 1 can be expressed by the following equation if the irregular radio wave propagation does not exist:

$$E_1 = \underline{a}\sqrt{P_1}/R \quad (1)$$

where R is the distance from a transmitting antenna to a reception antenna, $\underline{a}$ is a proportional coefficient and P_1 is the transmitting power of the antenna.

In the public cellular radio telephone system, the radius of the cell is determined at a boundary where the ratio S_1/I_1 of the intensity S_1 of the received f_1 wave to the intensity I_1 of the f_1 wave interference from outside the cluster 13, so that the the quality of telephone voice is kept a predetermined level.

The transmitting power P_2 of the private radio telephone system O of the present invention is kept to a value so that the ratio of the intensity S_2 of the transmitting f_2 wave to the intensity I_2 of the f_2 wave interference at the boundary of the local service area satisfies the conditions below:

$$\left.\begin{array}{l} S_2/I_2 = S_1/I_1 \\ P_2 \text{ is below the upper limit value that} \\ \text{does not interfere the other private} \\ \text{radio telephone systems adjacent} \\ \text{thereto.} \end{array}\right\} \quad (2)$$

Fig. 3 is a structural view of the portable radio telephone system in accordance with one embodiment of the present invention. A private branch exchange (PBX) 15 for wired telephone subscribers is disposed in the private radio telephone system O (corresponding to O in Fig. 1) and radio telephone subscriber circuits are added thereto. The radio telephone subscriber circuits are connected to transmission/reception antennas 18, 19 through transceivers (TRX) 16 and a booster 17, and the f_2 wave having the intensity that can suppress the f_2 wave interference of the public cellular radio telephone system, is transmitted from the antennas and enables the portable telephone set 20 to communicate by receiving the f_2 wave from the antennas.

As will be described elsewhere, the portable telephone set 20 can communicate with the f_1 wave from the cell 1 of the public cellular radio telephone system. The transmitting power of the portable telephone set 20 is also determined to a value that satisfies the condition of eq. (2). This controlling is made automatically by a radio frequency controller disposed inside the the private branch exchange (PBX) 15. The method controlling the transmission power for the private radio telephone system is the same as the method used for the heretofore known public cellular radio telephone system.

Fig. 4 shows the relation of the f_N wave (N = 1 ~ 12) of the radio frequency channel with Fig. 1 when the private radio telephone system is disposed for each of the cells inside the cluster 13. For example, the cells 4, 2, 5 in Fig. 1 use the f_5, f_3 and f_6 waves, respectively.

When a plularity of private radio telephone systems are disposed for each of the cells inside one cluster, the total interference intensity must be determined below a predetermined level. However, the condition which prevents the interference to the nearest adjacent system of the present invention is far more severe. As the radiation from an outdoor antenna shown in Fig. 3 is particulary severe, the interference is restricted by providing the antenna with directivity.

Furthermore, when a plurality of private radio telephone systems exist extremely close to one another inside the small cell, the service area of the private radio telephone system of the present invention becomes extremely narrow in order to prevent their mutual interference. To solve this problem, other radio frequency channels (e. g. alternate use of f_2 and f_3 waves in the cell 1) are used for the adjacent private branch telephone systems.

Fig. 5 shows the construction of the portable radio telephone system in accordance with another embodiment of the present invention. In this embodiment, a plurality of radio frequency channels are reused in one local area.

A transceiver (TRX) 21 having a radio wave transceiver and an antenna is disposed inside a building while a transceiver (TRX) 22 is disposed outside the building, and the radio frequency channels, the transmission power and the antenna directivity are selected so that they do not interfere with each other. The private branch exchange (PBX) 15 is equipped with a radio frequency controller, and when the portable telephone set 20 moves from the f_2 area to the area of f_3, it detects automatically the movement and switches the channels in the same way as the public cellular radio telephone system. If the radio frequency controller selects the empty channel(s) of both the public cellular radio telephone system and the other private radio telephone systems inside the cluster, the quality of the telephone voice is highly improved.

The district in which the portable radio telephone system of the present invention is disposed is not restricted to the cell disposition shown in Fig. 1.

Figs. 6 and 7 show an example of sector cell allotment. Each cell is divided into six sectors and four cells = 24 sectors form a unit cluster. A multibeam antenna having 60° directivity is disposed at the center of the hexagonal cell. The frequency channel of each sector is reused among the clusters where a public cellular radio telephone system is in service. Fig. 7 shows the sector number of the frequency channel corresponding to Fig. 6 when the private radio telephone system of the present invention is disposed inside each sector, and the system double reuses the radio frequency channel inside the sector. Other examples of sector numbers of the frequency channels can of course exist in the same way as the case of 12-cell unit

sectors in Fig. 1. When the wave interference is taken into consideration for sector cells, the directivity of the antenna becomes an important factor, and the gain function $G(\theta)$ must be introduced in the proportional coefficient $a = a_0 G(\theta)$ of eq. (1).

In a district where the number of subscribers of the public cellular radio telephone system becomes large, the traffic per unit area is increased by reducing the radius of the cell. The portable radio telephone system of the present invention is designed in consideration of this increase inside the respective area. Table 1 illustrates the radius of the service area of the private radio telephone system and the radius of the cell of the public cellular radio telephone system.

Table 1

Transmission power of antenna (19) of personal mobile telephone system of this invention and service area					
A	cell radius	5 km	3 km		1.5 km
	transmission power	25 W	9 W		2.5 W
B	service area radius	500 m	300 m	150 m	50 m
	transmission power	250 mW	90 mW	25mW	2.5 mW
Note: Sensitivity of reception system is assumed equal to that of public system.					

If a large number of mini cells must be disposed inside the local area, a plurality of radio frequency channels also must be reused in the private radio telephone system. In this case, the radius of the mini cell becomes much smaller than the maximum radius of the service area shown in Table 1.

In the actual cases, the shape of the cell is not so ideal as the ideal cell disposition shown in Fig. 1 and 6, and the power of the transmitted radio wave attenuates more rapidly than eq. (1). However, the application of the present invention is not essentially changed by these factors.

Fig. 8 shows the construction of a telephone set used in the portable telephone system described above.

In the drawing, reference numeral 23 represents an antenna and 24 does an antenna distributor for sending the reception signal from the antenna to a receiver and applying a reception signal from the receiver to the antenna 23. Reference numerals 24 and 26 represent frequency synthesizers for operating a transmitter 27 and a receiver 25 on predetermined channels. A control part 28 receives, as its input signals, the reception signal from the receiver 25, a reception level signal of the reception signal by a reception signal level detector 30 and signals from a handset 29 having a microphone M, a speaker R and key pads K, and supplies predetermined signals to the receiver 27, a transmitting power controller 31 and the frequency synthesizer 26.

Since the construction of the portable telephone set is substantially the same as the construction of a mobile telephone set used in the heretofore known urban mobile telephone system (such as the telephone set described in "The Bell System Technical Journal", Vol. 58, No. 9, pp. 132), its detailed description is hereby omitted.

The first characterizing feature of this embodiment lies in that a small output level, which is used for the private radio telephone system, is set to the output power controller 31 of the portable telephone set so that it can be used commonly for both the public cellular radio telephone system and the private radio telephone system. This is because the reception sensitivity of the local base station can be made substantially equal to that of the large area cellular radio telephone system and the distance between the portable telephone set and the station is small.

Fig. 9 shows the levels of the output power that can be accepted by the output power controller 31 for North America and Japan. In the case of the public cellular radio telephone system of North America, the minimum power is stipulated to 6 mW of the level 7, but 2.5 mW of the level 8 and 1 mW of the level 9 are further added in order to use it for the system of the present invention. In the case of the public cellular radio telephone system of Japan, the minimum power level is 160 mW of the step 1, but 25 mW, 5 mW and 1 mW of the levels 2, 3 and 4 are further added for the system of the present invention.

In other words, the portable telephone set of Fig. 8 has a switch portion for the power levels necessary for communication in the cells (1 - 12) shown in Fig. 1 and the communication power levels necessary for the private radio telepone system (e.g. 0.14) inside the cell (1) described above.

The second characterizing feature of the portable telephone set shown in Fig. 8 lies in that it has switch means for changing over the modes of use as desired by an operator to a mode where communication can

be made by utilizing the private radio telephone system when the telephone set enters the local service area of the private radio telephone system.

When the mode switch 32 is manually changed from the contact P to C, the frequency channel of the frequency synthesizer 26 and the level range of the transmitting power controller 31 are forcedly set to the state where the control signal of the private radio telephone system can be received. In other words, the switch 32 selects the combination of the frequency channels of the communication system of the cells (1 - 12) of Fig. 1 with the power levels and the frequency channels of the private radio telephone system (e.g. 0.14 in Fig. 1) with the transmitting power levels.

This mode switch 32 may be of an automatic type. Namely, a reception level judging detector 33 represented by dash line in Fig. 8 is disposed. In the public cellular radio telephone system, when the telephone set is under the waiting state where it receives the control signal from its station, it receives the time slot for calling other subscribers for the most of the time. This waste time is utilized in order to receive the control signal in the private radio telephone system and when the reception intensity is at a sufficiently high level, the mode switch can be changed over automatically.

As described above, the present invention provides the following effects.

(1) In accordance with the present invention, the radio frequency channels used in the existing public cellular radio frequency system are reused when disposing a private radio telephone system. Accordingly, the use of new frequency resources is not necessary.

(2) In accordance with the present invention, when the portable telephone set is brought into an area where the public cellular radio telephone system is in service, direct access can be made from the telephone set. Accordingly, radio wave attenuation due to buildings or the like does not occur and the toll for the public cellular radio telephone system is not necessary.

(3) In accordance with the present invention, the mobile telephone set that can make direct access to both the public cellular radio telephone system and the private radio telephone system can be accomplished without increasing a radio frequency circuit at the portable telephone set. Therefore, the portable set can be made compact in size and simple in construction and can be produced economically.

Claims

1. A portable radio telephone system for use in a communication area which is divided into a plurality of cluster areas (13), each of said cluster areas being further divided into a plurality of cellular areas (1-12), wherein the same radio frequency channels are repeated for each of said cluster areas, while respective ones of said radio frequency channels are allocated to said respective cellular areas in each cluster area, and for effecting radio communication by means of a portable radio telephone set by use of selected ones of said allocated frequency channels, said portable radio telephone system comprising:
   a plurality of antennas (18, 19) provided in a local area (0) disposed inside one (1) of said cellular areas for transmitting and receiving radio waves;
   a portable radio telephone set (20) for carrying out radio communication by means of one of said radio frequency channels;
   a private branch exchange (15) disposed within said local area; and
   a transmission/reception circuit (16, 17) connecting said antennas to said private branch exchange,
   wherein radio communication is carried out inside said local area by said portable radio telephone set by use of radio waves of said allocated frequency channels of cellular areas, said frequency channels allocated to the radio communication inside said local area being different from the frequency channel allocated to the cellular area in which said local area is disposed and the power intensity of said radio waves for radio communication inside said local area is kept below a certain value, so that the public cellular network is not interfered with.

2. A portable radio telephone system according to claim 1, wherein said local area lies within a building structure.

3. A portable radio telephone system according to claim 1 or 2, wherein frequency channels different from said frequency channels allocated to cellular areas adjacent to said cellular area in which said local area is disposed are used for radio communication.

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2. A portable radio telephone system according to claim 1, wherein said local area lies within a building structure.

3. A portable radio telephone system according to claim 1 or 2, wherein frequency channels different from said frequency channels allocated to cellular areas adjacent to said cellular area in which said local area is disposed are used for radio communication.

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4. A portable radio telephone system according to any of the preceding claims, wherein said local area disposed in one of said cellular areas consists of a plurality of mini areas, and antennas are disposed in respective of said mini areas and transmit and receive radio waves of mutually different frequencies.

5. A portable radio telephone system according to any of the preceding claims, wherein said portable radio telephone set includes controller (28, 32) for receiving a control signal from a base station which is disposed in one of said cellular areas or a control signal from said private branch exchange which is disposed in said local area in said one of said cellular areas on the instructions of a user having said portable radio telephone set selectively.

Patentansprüche

1. Tragbares Funktelefonsystem zur Verwendung in einem Kommunikationsbereich, der in eine Vielzahl von Clusterbereiche (13) aufgeteilt ist, wobei jeder der Clusterbereiche weiter in eine Vielzahl von zellularen Bereichen (1 bis 12) aufgeteilt ist, worin die gleichen Funkfrequenzkanäle für jeden der Clusterbereiche wiederholt werden, während jeweilige der Funkfrequenzkanäle jeweiligen zellularen Bereichen in jedem Clusterbereich zugeordnet sind, und zum Durchführen von Funkkommunikation mit Hilfe eines tragbaren Funktelefongeräts unter Verwendung von ausgewählten der zugeordneten Frequenzkanäle, wobei das tragbare Funktelefonsystem aufweist:
eine Vielzahl von Antennen (18, 19), die in einem lokalen Bereich (0) bereitgestellt sind, angeordnet innerhalb eines (1) der zellularen Bereiche zum Senden und Empfangen von Radiowellen;
ein tragbares Funktelefongerät (20) zum Ausführen von Funkkommunikation mit Hilfe eines der Funkfrequenzkanäle;
eine Nebenstellenvermittlung (15), die in dem lokalen Bereich angeordnet ist; und
eine Sende-/Empfangsschaltung (16, 17) die die Antennen mit der Nebenstellenvermittlung verbindet,
wobei Funkkommunikation innerhalb des lokalen Bereiches ausgeführt wird durch das tragbare Furktelefongerät unter Verwendung von Radiowellen der zugeordneten Frequerzkanäle zellularer Bereiche, wobei die Frequenzkanäle, die der Funkkommunikation innerhalb dem Lokalbereich zugeordnet sind, unterschiedlich von den Frequenzkanälen sind, die dem zellularen Bereich zugeordnet sind, in dem der lokale Bereich angeordnet ist, und wobei die Leistungsintensität der Radiowellen zur Funkkommunikation innerhalb dem lokalen Bereich unter einem bestimmten Wert gehalten wird, so daß das öffentliche zellulare Netzwerk nicht gestört wird.

2. Tragbares Funktelefonsystem gemäß Anspruch 1, worin der lokale Bereich innerhalb einer Gebäudestruktur liegt.

3. Tragbares Funktelefonsystem gemäß Anspruch 1 oder 2, worin Frequenzkanäle, unterschiedlich von den Frequenzkanälen, die den zellularen Bereichen zugeordnet sind, die dem zellularen Bereich benachbart sind, in dem der lokale Bereich angeordnet ist, zur Funkkommunikation benutzt werden.

4. Tragbares Funktelefonsystem gemäß einem der vorhergehenden Ansprüche, worin der lokale Bereich, der in einem der zellularen Bereiche angeordnet ist, aus einer Vielzahl von Minibereichen besteht, und wobei Antennen in jeweiligen der Minibereiche angeordnet sind und Radiowellen von wechselseitig verschiedenen Frequenzen senden und empfangen.

5. Tragbares Funktelefonsystem gemäß einem der vorhergehenden Ansprüche, worin das tragbare Funktelefongerät eine Steuereinrichtung (28, 32) zum Empfangen eines Steuersignales von einer Basisstation aufweist, die in einem der zellularen Bereiche angeordnet ist, oder ein Steuersignal von der Nebenstellenvermittlung, die in dem lokalen Bereich in einem der zellularen Bereiche angeordnet ist, auf Anweisungen eines Benutzers, der das tragbare Funktelefongerät ausgewählt hat.

Revendications

1. Système de radiotéléphone portable destiné à être utilisé dans une zone de communication, qui est divisée en une pluralité de zones de regroupement (13), chacune desdites zones de regroupement étant en outre divisée en une pluralité de zones cellulaires (1-12), les mêmes canaux de radio fréquences étant répétés pour chacune desdites zones de regroupement, tandis que des canaux respectifs faisant partie desdits canaux de radio fréquences sont affectés auxdites zones cellulaires

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respectives dans chaque zone de regroupement, et destiné à établir une radio communication au moyen d'un appareil radiotéléphonique portable moyennant l'utilisation de certains sélectionnés desdits canaux de fréquences alloués, ledit système de radiotéléphone portable comprenant :
une pluralité d'antennes (18,19) prévues dans une zone locale (O) située à l'intérieur de l'une (1) desdites zones cellulaires pour l'émission et la réception d'ondes radioélectriques;
un appareil radiotéléphonique portable (20) pour exécuter une radio communication au moyen de l'un desdits canaux de radio fréquences;
un central privé (15) disposé à l'intérieur de ladite zone locale; et
un circuit d'émission/réception (16,17) raccordant lesdites antennes audit central privé,
une radio communication étant exécutée à l'intérieur de ladite zone locale au moyen dudit appareil radiotéléphonique portable moyennant l'utilisation d'ondes radioélectriques desdits canaux de fréquences affectés de zones cellulaires, lesdits canaux de fréquences affectés à la radio communication à l'intérieur de ladite zone locale étant différents du canal de fréquences alloué à la zone cellulaire, dans laquelle ladite zone locale est située, et l'intensité de puissance desdites ondes radioélectriques pour une radio communication à l'intérieur de ladite zone locale est maintenue inférieure à une certaine valeur, de manière à empêcher toute perturbation du réseau cellulaire public.

2. Système de radiotéléphone portable selon la revendication 1, dans lequel ladite zone locale est située à l'intérieur d'une structure de bâtiment.

3. Système de radiotéléphone portable selon la revendication 1 ou 2, dans lequel des canaux de fréquences, qui diffèrent desdits canaux de fréquences affectés auxdites zones cellulaires adjacentes à ladite seconde zone cellulaire, dans laquelle ladite zone locale est disposée, sont utilisés pour une radio communication.

4. Système de radiotéléphone portable selon l'une quelconque des revendications précédentes, dans lequel ladite zone locale située dans l'une desdites zones cellulaires est constituée par une pluralité de mini-zones, et des antennes sont disposées dans lesdites mini-zones respectives et émettent et reçoivent des ondes radioélectriques possédant des fréquences réciproquement différentes.

5. Système de radiotéléphone portable selon l'une quelconque des revendications précédentes, dans lequel ledit poste radiotéléphonique portable comprend un dispositif de commande (28,32) servant à recevoir un signal de commande depuis une station de base, qui est disposée dans l'une desdites zones cellulaires, ou un signal de commande provenant dudit central privé, qui est situé dans ladite zone locale dans ladite zone cellulaire, et ce de façon sélective sur la base des instructions d'un utilisateur possédant ledit appareil radiotéléphonique portable.

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