A method and apparatus are provided for separating spectrally diverse radio frequency signals. The apparatus includes means, within a signal transfer module (23), for transferring an input signal received at a first port of the signal transfer module (23) to a second port of the signal transfer module. At least one frequency selective assembly (37, 24) is included, interconnected with the second port of the signal transfer module, presenting a characteristic impedance to a desired signal of the input signal and reflecting of their signals of the input signal to the second port of the frequency transfer module. A means, within the signal transfer module for transferring a reflected signal received at the second port of the signal transfer module to a third port of the signal transfer module is also included. A first antenna (31) is interconnected with the frequency selective cavity assembly for transmission of the desired signal. A second antenna (30) is interconnected with the third port of the signal transfer module for transmission of the other signals. The method of practising the invention is also provided.
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METHOD AND APPARATUS FOR SEPARATING CHANNELS FROM A RADIO FREQUENCY TRANSMITTER

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Field of the Invention

The field of the invention relates to communication systems and, more particularly, to cellular communication systems.

10 Background of the Invention

Cellular systems simultaneously handling a number of traffic channels through each base station are typically assigned a number of channels \((f_1-f_n)\) in support of communications with mobile communication units through local base stations. Each base station is, in turn, allotted a subset of the channels \((f_1-f_n)\). Of the subset of channels assigned to a base site at least one (and often more) is designated as a control channel for purposes of access control and channel set-up.

Communication with a communication unit on a traffic channel within a service coverage area of the base site is often accomplished through an omnidirectional antenna centrally located within the service coverage area. A number of communications may be simultaneously supported through the antenna with each individual communication supported by a transmitter (located at the base site) assigned to the traffic channel. Each transmitter includes a modulated transmit signal source within the transceiver and a radio frequency (RF) power amplifier. Each transmitter thereby provides signal generation, modulation and amplification.

35 In contrast to traffic channels, control information from a base site is often transceived from a number of directional antennas that divide the service coverage area into a number of sectors. Dividing the service
coverage area into sectors for control channel purposes provides a means for the base site to determine the relative position of a communication unit for purposes of handoff.

The simultaneous transmission of a number of traffic channel signals from the central antenna requires that transmitter output of each active transceiver be combined before application to, and transmission from, the central antenna. In order to avoid interference-producing intermodulation products, signals must be combined after any non-linear steps within the amplification process. In addition, the combining topology must provide sufficient reverse isolation to insure that signals of parallel amplification branches will not be coupled into the output of other power amplifiers, again producing intermodulation products.

Where each transceiver is equipped with its own power amplifier (PA), combining must occur after the PA where signal levels, as well as combining losses, are high. A cavity combiner, for combining such high level RF signals while providing the necessary isolation, is provided by U.S. Patent No. 4,667,172 assigned to the assignee of the present invention.

An explanation of the operation of a cavity combiner and of the interconnecting one-quarter wavelength interconnect facilities follows. A cavity combiner includes a number of frequency selective cavities, each resonant at a tuned frequency, interconnected at a combiner junction by a transmission line of a length essentially equal to one-quarter wavelength at the tuned frequency. A number of such frequency selective cavities and one-quarter wavelength cables (cavity assemblies) interconnected at a combiner junction, provide a means for combining a number of RF signals.

A cavity combiner presents (at the tuned frequency) an impedance equal to that of the characteristic (matched) impedance of the system.
(typically 50 Ω) to a desired signal frequency from an amplifier through the frequency selective cavity to the combiner junction. A signal presented at the cavity combiner, in the reverse direction, from the combiner junction, at other than the tuned frequency, would be presented with a low impedance. The low impedance is transformed by the one-quarter wavelength cable into a high impedance at the combiner junction. The high impedance at the combiner junction prevents adjacent combiner branches from mutually loading one another, while the cavity selectivity provides an adequate level of signal isolation between adjacent branches.

While the process of combining high level RF signals works well the power loss, in terms of actual power dissipation, is significant. Power loss within a combiner is typically 3 db.

A circulator is known to transfer RF signals received at a first port to a second port and to a load interconnected with the second port. If an impedance mismatch is presented at the second port, a proportional amount of the RF signal is reflected back and becomes an input at the second port of the circulator. Since the circulator transfers input signals received at a second port to a third port, the reflected RF signal is transferred to (and dissipated) within a load often interconnected with the third port.

Radio frequency (RF) circulators are known in the art of RF communications (see, for example, U.H.F. Techniques for Lumped Constant Circulators, by J. Helszajn and F. M. Aitkent, Electronic Engineering, Nov., 1973) and used for purposes of signal steering, switching, isolating, etc. The most common use of circulators is to protect RF transmitter from damage due to open-circuits between the transmitter and an associated load.

In other communication systems, transceivers are not equipped with individual PAs; instead, a common, multitone linear PA (LPA) is used for amplification after
the RF signals have been combined at relatively low power levels at the output of the transceiver. The use of such common LPA for traffic channels in systems using a common antenna has resulted in considerable simplification of system topology, improvements in system efficiency, and reduction in system size. In other systems, operating under a sector format, the use of LPAs is not as attractive because of the difficulty in separating RF signals following amplification in the LPA.

Because of the importance of power efficiency in communication systems a need exists for a method of isolating RF channels for sector transmission following amplification in a common LPA.

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Summary of the Invention

A method and apparatus is provided for separating spectrally diverse radio frequency signals. The apparatus includes means, within a signal transfer module, for transferring an input signal received at a first port of the signal transfer module to a second port of the signal transfer module. At least one frequency selective assembly is included, interconnected with the second port of the signal transfer module, presenting a characteristic impedance to a desired signal of the input signal and reflecting other signals of the input signal to the second port of the frequency transfer module. A means, within the signal transfer module for transferring a reflected signal received at the second port of the signal transfer module to a third port of the signal transfer module is also included. The method of practicing the invention is also provided.

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Brief Description of the Drawings
FIG. 1 is a block diagram of a communication system base site in accordance with an embodiment of the invention.

Detailed Description of the Preferred Embodiment

The solution to the problem of separating previously combined RF signals (following amplification in a common LPA) lies conceptually in the use of a signal transfer module (e.g., an RF circulator) and a frequency selective cavity assembly interconnected with a second port of the signal transfer module. It has been determined that the use of a signal transfer module in conjunction with a frequency selective cavity assembly produces the unexpected result of separating a first RF signal, of a frequency to which the cavity is tuned, for application to a first antenna while routing other signals to a second antenna. Such a device has been determined to be useful in cellular system base sites (e.g., where traffic channels are transmitted from a common, omni antenna and control channels are transmitted from sector antennas).

The output of an LPA (containing a control channel to be separated from a number of traffic channels) is applied to a first port of the circulator. An RF input presented to a first port of a circulator, as is known in the art, will be transferred to the second port of the circulator. In a system having a characteristic impedance (e.g., 50 Ω), the frequency selective cavity assembly, interconnected with the second port of the circulator, presents a 50Ω path for the control channel, to which it is tuned, to a sector antenna and a high impedance path at the cavity junction for the traffic channels (outside a pass band of the cavity). The high impedance presented to the traffic channel signals at the cavity junction causes the traffic channel signals to be reflected back into the second port of the circulator. The circulator, receiving an input RF signal at its second
port, transfers the reflected RF signal to a third port of the circulator. An omni antenna interconnected with the third port of the circulator presents a load to the circulator and a path for transmission of the traffic signals.

The frequency selective cavity assembly includes a frequency selective cavity and a transmission line interconnecting the frequency selective cavity to the second port of the circulator. The transmission line is essentially one-quarter wavelength long at the frequency band of the desired control channel. Each frequency selective cavity is tuned to the frequency of one selected control channel.

FIG. 1 is a block diagram of a cellular base site in accordance with an embodiment of the invention.

The base site has a single omni antenna 30 and a number of sector antennas 31-36. The omni antenna is used generally for transmitting traffic channels within a service coverage area (not shown) of the base site 10. The sector antenna 31-36 are each used for transmitting control information within a portion (e.g., a 60 degree sector of the service coverage area.

Traffic channel information originating from within a public switch telephone network (PSTN) or another base site 10 is routed to appropriate traffic channel transceivers 13-14 by the controller 12. Control information originating within the controller 12 is also routed to control transceivers 15-20. The low-level output signals of the transceivers 13-20 are combined within the combiner 21 through resistive combining techniques for subsequent amplification within the LPA 22. Within the LPA 22 the combined signals are amplified to a level sufficient for transmission from the omni 30 or sectored 31-36 antennas.

Following amplification within the LPA 22 the combined signal is applied to port 1 of the circulator 23. The combined signal is transferred to port 2 of the
circulator 23. At the output of port 2 the signal passes through a splitting junction 43 and a number of transmission lines 37-42 to frequency selective cavities 24-29.

Each frequency selective cavity 24-29 is tuned to the frequency of a control channel to be transmitted through the associated sector antenna 31-36. The interconnected cables 37-42 have a length substantially equal to one-quarter the wavelength at the desired control channel frequency.

The use of the one-quarter wavelength cable (of the typical characteristic impedance of typically 50Ω) and frequency selective cavity presents a low loss path to the desired control channel signal for transmission from the associated sector antenna. The characteristic impedance presented by the frequency selective cavity assembly also prevents a reflection of the desired control channel signal back to the junction 43 or to the second port of the circulator 23.

Traffic channel frequencies reaching the junction 43, on the other hand, are presented with a high impedance. Upon reaching the junction 43, the reflected traffic channel signals (undesired signals) are reflected back to the second port of the circulator 23. Upon being reflected into the the circulator (as an input), the undesired signals are transferred to the third port of the circulator 23. The omni antenna 30 interconnected to the third port of the circulator 23 presents a load for the traffic channel signals and a path for transmission of the signals.

The use of the circulator 23 and frequency selective cavity assemblies improves communication systems by reducing the cost and improving the reliability and efficiency of such systems. The use of a common LPA reduces the cost of transmitters within such a system by reducing the parts required to build such as system and by utilizing the LPA to a higher capacity for a better efficiency. The use of a common
LPA allows for a reduction in the size of such a system by concentrating power amplification to a single area. The use of a common LPA further allows the dynamic changing of system topologies (e.g., the reassignment of transceiver from one service coverage area to another).

The many features and advantages of this invention are apparent from the detailed specification and thus it is intended by the appended claims to cover all such features and advantages of the system which fall within the true spirit and scope of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art (e.g., use within commercial transmission systems), it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly all suitable modifications and equivalents (e.g., omni-sector, sector-omni, omni-omni, and sector-sector channel separators) may be resorted to, falling within the scope of the invention.

An omni-sector separator may be used, for instance, where a separated control channel is transmitted on an omni antenna and reflected traffic channels are transmitted from directional antennas. An omni-sector channel separator may also find usefulness in cases where geographic obstructions cause poor illumination of a service area from the central omni antenna, which can be remedied by a single channel sector antenna placed in close proximity and powered from the same LPA. An omni-sector channel separator may further find usefulness in cases where geographic conditions cause interference to other service areas on selected channels radiated from the central omni antenna by separating those channels and radiating them from sector antennas into specific service areas. A sector-sector channel separator may be useful where directional antenna for traffic and control do not coincide.
It is, of course, to be understood that the present invention is, by no means, limited to the specific showing in the drawing, but also comprises any modification within the scope of the appended claims.
Claims

1. An apparatus for separating spectrally diverse radio frequency signals comprising: means, within a signal transfer module, for transferring an input signal received at a first port of the signal transfer module to a second port of the signal transfer module; at least one frequency selective assembly interconnected with the second port of the signal transfer module, presenting a characteristic impedance to a desired signal of the input signal and reflecting other signals of the input signal to the second port of the frequency transfer module; means, within the signal transfer module for transferring a reflected signal received at the second port of the signal transfer module to a third port of the signal transfer module.

2. The apparatus as in claim 1 wherein the signal transfer module further comprises a radio frequency circulator.

3. The apparatus as in claim 1 wherein the at least one frequency selective assembly comprises a frequency selective cavity, resonant at a frequency of the desired signal, interconnected with the second port of the signal transfer module with a cable of a length substantially equal to one-quarter wavelength of the frequency of the desired signal.
4. An apparatus for separating a first radio channel and an at least second channel within a high power radio signal, such apparatus comprising: a circulator receiving the high power radio signal at a first port; and a frequency selective cavity, selective of the first frequency, interconnected with the circulator through a first terminal of the frequency selective cavity and a second port of the circulator, through a transmission line of a length substantially equal to one-quarter wavelength of a frequency of the first channel.

5. The apparatus as in claim 4 further comprising at least a second frequency selective cavity, selective of at least a second frequency, interconnected with the circulator through a first terminal of the at least second frequency selective cavity and the second port of the circulator, through a transmission line of a length substantially equal to one-quarter wavelength of a frequency of the at least second channel and with an at least third antenna through a second terminal of the at least second frequency selective cavity.
6. In a high power radio signal from a radio frequency transmitter producing a combined signal containing a signal of a first radio channel for transmission through a first antenna and at least a signal of a second radio channel for transmission through a second antenna, a method for separating the signals for transmission through respective antennas comprising the steps of: applying the combined signal to a circulator at a first port; outputting the combined signal to a first frequency selective cavity, selective of the first frequency, at a second port of the circulator through a conductor of a length substantially equal to one-quarter wavelength of a frequency of the first channel; coupling an output of the first frequency selective cavity to the first antenna; and transmitting the first channel through the first antenna.

7. The method as in claim 6 further including the step of outputting at a third port the portion of the combined signal received as an input at the second port and transmitting the portion of the combined signal from a second antenna interconnected with the third port of the circulator.
8. In a high power radio signal from a radio frequency transmitter producing a combined signal containing a signal of a first control channel for transmission through a first directional antenna and a signal of an at least a first traffic channel for transmission through an omni antenna, an apparatus for separating the first control channel from the at least first traffic channel comprising: a circulator receiving the combined signal at a first port; a frequency selective cavity, selective of the first control channel, interconnected with the circulator through a first terminal of the frequency selective cavity and a second port of the circulator, through a transmission line of a length substantially equal to one-quarter wavelength of a frequency of the first control channel and with the first antenna through a second terminal of the frequency selective cavity; and an interconnection with the omni antenna at a third port of the circulator.

9. The apparatus as in claim 8 further comprising at least a second frequency selective cavity, selective of at least a second control channel, interconnected with the circulator through a first terminal of the at least second frequency selective cavity and a second port of the circulator, through a transmission line of a length substantially equal to one-quarter wavelength of the at least second control channel and with an at least second directional antenna through a second terminal of the at least second frequency selective cavity.

10. The apparatus as in claim 8 wherein the radio frequency transmitter further comprises a base station in a cellular communication system.
### INTERNATIONAL SEARCH REPORT

**International application No.**

PCT/US94/03007

### A. CLASSIFICATION OF SUBJECT MATTER

- **IPC(5)**: H04B 01/02
- **US CL**: 455/103

According to International Patent Classification (IPC) or to both national classification and IPC

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

- **U.S.**: 455/103, 102, 101, 272, 275, 279, 1, 120, 121, 80, 81, 13.3; 333/126, 1.1, 129, 132, 134

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

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  - "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

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Date of the actual completion of the international search: 14 JUNE 1994

Date of mailing of the international search report: 10 AUG 1994

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