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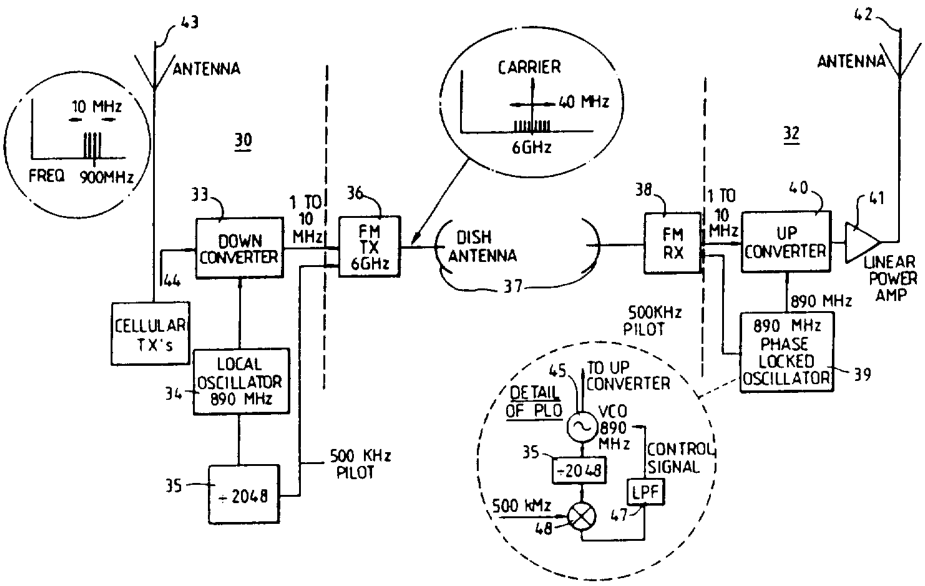

(57) Abstract

A method of transferring a modulated radio frequency signal from a first site, for example a macrocellular mobile communications base station, to a second site, for example a microcellular mobile communications base station. The method comprising deriving, at the first site, from one reference oscillator both a conversion signal and a pilot signal, utilising the conversion signal to downconvert the modulated radio frequency signal, and sending both the downconverted modulated signal and the pilot signal to the second site via a common communications link. At the second site a second conversion signal is derived from the pilot signal and is used to reform the modulated signal.

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Transmission via a Common Communication Link of both a Downconverted Modulated Radio Frequency Signal and a Pilot Signal Used for Conversion

This invention relates to signal transmission techniques and in particular to techniques for transferring a modulated radio frequency signal from a central site to a remote transmitter by radio.

There are a number of scenarios in the provision of mobile radio communication in which it is desirable to provide a copy of a modulated radio frequency signal transmitted from a first site, at a second site remote from the first. For example, in a cellular radio communications network it is often found that part of a cell is not well served by transmissions from the cell's central base station antenna, and a further, remote antenna is positioned in this part of the cell to reproduce the base station antenna's transmissions. Clearly given the stringent frequency control requirements of such cellular radio networks it is essential that the remote antenna transmits a substantially identical RF signal to that transmitted by the base station antenna.

Another use of remote antennas occurs in micro-cellular mobile radio communications networks. Normally the modulated RF signal for transmission in the micro-cell is formed at the micro-cell's base station from baseband signals sent to it from the macro-cell base station. If however the micro-cell base station is replaced by a remote antenna the fully formed modulated RF signal for transmission by the remote antenna can be supplied from a central site, perhaps located at a macro-cell base station. This would allow all signalling and multiplexing equipment serving the micro-cell to be centrally located thus reducing remote site requirements and costs, and furthermore would allow changes to the micro-cell frequency plan and/or modulation format to be done at the central location.

Macro-cellular networks utilising sectored cells could also benefit from the use of remote antennas for similar reasons. These uses are discussed by Fye in his paper "Design of Fiber Optic Antenna Remoting Links for Cellular Radio Applications" given at The Vehicular Technology Conference 1990, and subsequently published by the IEEE.

A known technique, discussed in the paper by Fye, for transferring a modulated RF signal from a central site to a remote transmitter comprises providing an optical fibre link between the central site and the remote transmitter.

The link has an optical transmitter (a laser), a transmission line (an optical fibre) and a receiver (a photodiode). The modulated RF signal is applied directly to the laser and amplitude modulates the optical output of the laser. This output is carried by the optical fibre to the photodiode where the RF signal is recovered from the optical carrier.

Since the RF signal directly modulates the laser it can be seen that the bandwidth of the optical signal generated will be much greater than the bandwidth of the RF signal. For example if the RF signal has a frequency of approximately 900 MHz and a bandwidth of approximately 10 MHz the bandwidth of the optical signal will be approximately 1800 MHz. Thus although this known technique for transferring a modulated RF signal from a first site to a second site is conceptually very simple and has practical advantages, the use made of the transmission capacity of the communications link is very inefficient.

This may not in the short term be a limiting factor in the use of this technique with optical fibre links since they have a very great transmission capacity. However, in some circumstances there is a need to provide a link between the central site and remote transmitter wholly or partly by radio. The large bandwidth required by the technique discussed above is a severe limitation if such a radio link is to be used. In addition to the generally lower transmission capacity of such links, because they are free-space links, spectral efficiency is an important consideration.

An object of the present invention is to provide a simple method of transferring a modulated RF signal from a first site to a second site via a communications link which, at least to some extent, ameliorates the requirements placed on the communications link by prior art methods.

It is known to reduce the effects of phase noise and drift in a radio transmission system by transmitting pilot signals over the radio link; see for example the United States patent 5109532 to Petrovic. In this United States patent a pilot signal is added to the modulated signal. In the receiver the local oscillator used to downconvert the incoming signal is controlled such that the sum of the downverted carrier frequency and the pilot frequency is held constant. The resulting signal includes a drift-free component. However, this system requires a local oscillator and a reference frequency generator at the receiving end. Moreover, the drift-free component is not at the input carrier frequency.

According to a first aspect of the present invention there is provided a method of transferring a modulated radio frequency signal from a first site to a second site, the method comprising the steps of:

1) at the first site, downconverting the modulated signal by mixing the modulated signal with a first conversion signal derived from a reference oscillator,
2) deriving a pilot signal from the reference oscillator,
3) sending both the downconverted modulated signal and the pilot signal from the first site to the second site via a common communications link,
4) at the second site, deriving a second conversion signal from the pilot signal, which second conversion signal is of a substantially identical frequency to the first conversion signal, and

5) reforming the modulated radio frequency signal by mixing the downconverted modulated signal with the second conversion signal.

An advantage of downconverting the modulated RF signal before transmission over the communications link is that the bandwidth required of the link is considerably reduced. Thus taking the previous example if the 900 MHz RF signal is downconverted to 10MHz the bandwidth required of the communications link will be approximately 20 MHz. However if the reformed modulated RF signal at the second site is to be accurate then the conversion signal used at the second site must be substantially identical in frequency to that used at the first site . To achieve this the invention provides at the first site a reference oscillator from which is derived both the conversion signal used to downconvert the modulated RF signal, and a pilot signal. The downconverted RF signal and the pilot signal are sent via the same communications link to the second site where the pilot signal is used to derive a substantially identical conversion signal to that used at the first site.

It should be noted that the frequency stability of the modulated RF signal transmitted at the second site is not affected by the frequency stability of the reference oscillator since any variation in the reference oscillator frequency will be reflected in both the conversion signal and the pilot signal frequencies.

Although the method of the present invention may be used with an optical fibre communications link, preferably the link is provided by a free-space radio frequency transmission system such as an FM microwave system. In this case the method provides particularly efficient use of the microwave spectrum while allowing access to the known linearity and noise advantages given by FM techniques, and ensuring that a substantially identical copy of the modulated RF signal is transferred from the first site to the second site.

The pilot frequency is preferably selected to be of a lower frequency than the down converted radio frequency signal so that they can be readily separated in the receiver by filters. The radio frequency signal typically comprises a plurality of multiplexed radio frequency channels, each channel being suitable for use in a mobile cellular radio communications system.

According to a second aspect of the invention there is provided apparatus for use, at the first site, in a method according to the invention, comprising:

a reference oscillator,

downconverting means,

means for deriving a conversion signal from the reference oscillator for use with the downconverting means,

means for deriving a pilot signal from the reference oscillator,

and transmitting means for transmitting a RF signal.

According to a third aspect of the invention there is provided apparatus for use at the second site, in a method according to the invention, comprising:

receiving means for receiving a RF signal,

generating means for generating a conversion signal from a received pilot signal, and

up converting means responsive to the conversion signal.

Preferred embodiments of the invention will now be described, by way of example only, and with reference to the accompanying figures, in which:

Figure 1 shows a prior art system, using an optical fibre communications link,

Figure 2 shows a prior art system using a radio frequency communications link,

Figure 3 shows a first arrangement according to the present invention, and

Figure 4 shows a second arrangement according to the present invention.

The prior art system shown in Figure 1 comprises a macrocell base station (10), a microcell base station (13) and an optical fibre communications link (12). The macrocell and microcell base stations comprise respective antennas (14) and (15) and the optical fibre communications link (12) comprises a laser (16), an optical fibre (17) and a PIN photodiode (18).

A modulated RF signal at 900 MHz (shown schematically in Figure 1(a)) transmitted by the macrocell base station antenna (14) is sampled within the macrocell at (11) and this signal is applied directly to the laser (16) of the optical fibre communications link (12). The output of the laser (16) (shown schematically in Figure 1(b)) has a modulation bandwidth of approximately 1800 MHz. This laser output is carried to the PIN photodiode (18) by the optical fibre (12). Here the 900 MHz modulated RF signal is recovered, passed to a linear power amplifier (19) and transmitted by the microcell base station antenna (15). Frequency accuracy of the retransmitted modulated RF signal is ensured because the whole of the signal transmitted by antenna (14) is used to modulate the laser (16).

The prior art method could, as shown in Figure 2, be used with a radio frequency communications link. Thus the communications link could comprise a microwave source (23), an amplitude modulator (24), a pair of microwave dish antennas (25), and a receiver (26). In this case the modulated RF signal fed to the amplitude modulator (24) is modulated onto a 6 GHz signal produced by the microwave source (23), and transmitted between the microwave dish antennas (25). At the receiver (26) the modulated RF signal is recovered by envelope detection, amplified and supplied to the antenna (29) for retransmission. However the consequent 1800 MHz modulation bandwidth required of the radio communications link (shown in Figure 2 (b)) is a very inefficient use of the available radio spectrum and there are few circumstances in which such a large bandwidth requirement would be acceptable.

In a first embodiment according to the present invention, shown in Figure 3, the macrocell base station (30) is provided with a down converter (33), a local oscillator (34) and a divider (35). The modulated 900 MHz RF signal transmitted by the macrocell base station (30) via antenna (43) (shown schematically in Figure 3 (a)) is sampled at (44) and fed to the down converter (33). This signal is mixed with a conversion signal from the local oscillator (34) which is at a frequency which differs from 900 MHz by at least the modulation bandwidth of the RF signal. The resulting low frequency (typically ~10 MHz), modulated signal is fed to the 6 GHz transmitter (36) of a FM microwave transmission system. Derived from the same local oscillator (34) by means of the divider (35) is a 500 KHz pilot signal. This pilot signal is also fed to the same transmitter (36). The signal transmitted by the FM system (shown schematically in Figure 3(b)) thus has a bandwidth of typically 40 MHz; due to FM side bands. For an AM system the bandwidth would be approximately 20 MHz.

At the FM receiver (38) this signal is demodulated in the conventional manner and the 10 MHz downconverted modulated signal and 500 KHz pilot signal are passed to the microcell base station.

The microcell base station (32) is provided with an upconverter (40), a phase locked oscillator (39), a linear power amplifier (41) and an antenna (42).

The 10 MHz signal is passed directly to the upconverter (40) whereas the 500 KHz pilot is used to derive a 890 MHz conversion signal for use with the upconverter. The phase locked oscillator comprises a voltage controlled oscillator (45) operating at approximately 890 MHz, a divider (35), mixer (48) and a low pass filter (47). The pilot signal at 500 KHz is used by the phase locked oscillator to exactly reproduce the conversion signal used in the macrocell base station (30). The pilot signal and the divided output of the oscillator are mixed at the mixer (48) and the resulting difference signal is passed, via the low pass filter, to the voltage controlled oscillator. The resulting conversion signal is fed to the upconverter (40) and, with the 10 MHz signal, precisely reforms the macrocell's modulated RF signal. The reformed signal is amplified to the required transmit power level by linear power amplifier (41) and transmitted by antenna (42).

Preferably the local oscillator (34) at the macrocell base station is also a voltage controlled oscillator and is locked to the output of a 500 KHz quartz crystal oscillator. This has the advantage of allowing the same circuitry to be used at both the macrocell and microcell base stations. At the macrocell base station the oscillator is locked to a 500 KHz crystal, while at the microcell base station the oscillator is locked to the incoming 500 KHz pilot signal, which is derived from the same 500kHz crystal.

The use of a low frequency for the pilot signal minimises phase and amplitude noise since in an FM system noise increases linearly with frequency.

Use of an FM rather than an AM radio system has the advantages of not requiring a linear transmitter, having high overall linearity over the system, and the well known FM noise advantage.

In a second embodiment of the invention, shown in Figure 4, the macrocell base station (50) is provided with a multiplier (51) rather than a divider, and the local oscillator (52) is operated at the low pilot signal frequency of 500 KHz. Hence the pilot signal is supplied to the FM transmitter (36) directly from the local oscillator while the 890 MHz conversion signal for use with the downconverter is generated by the multiplier (51). The microcell base station is provided with an identical multiplier (51) and the need for an oscillator at this base station is thus eliminated. At the microcell base station the 500 KHz pilot signal is simply passed through the multiplier (51) to generate a 890 MHz conversion signal for use with the up converter. This second embodiment has the further advantage of being less susceptible to phase noise.

In further embodiments of the invention a divider could be used at the first site and a multiplier at the second site, and vice versa.

In a typical mobile communications system, in which radio transmissions pass in both directions over the radio link, a similar up and down conversion is required for each direction of transmission. For this purpose the base station and remote site may each be equipped with a local oscillator to provide the down conversion reference frequency and the pilot signal for transmission to the other station for the upconversion of the signal received there. However, alternatively the pilot signal sent from the first site to the second site may be used at the second site both for up conversion of the signals received at the second site, as described above, and for the reference signal for the down conversion of the signals that the second site transmits itself. The reference oscillator at the first site will then provide the reconversion reference frequency at the first site directly. The reference oscillator may be located at either the base station or the remote site, however, if the base station communicates with more than one remote site the same reference oscillator, if located at the base station, may be used for all the links.

This arrangement removes the need to have a local oscillator at the second site.

CLAIMS

1. A method of transferring a modulated radio frequency signal from a first site to a second site, the method comprising the steps of:

1) at the first site, downconverting the modulated signal by mixing the modulated signal with a first conversion signal derived from a reference oscillator,
2) deriving a pilot signal from the reference oscillator,
3) sending both the downconverted modulated signal and the pilot signal from the first site to the second site via a common communications link,
4) at the second site, deriving a second conversion signal from the pilot signal, which second conversion signal is of a substantially identical frequency to the first conversion signal, and
5) reforming the modulated radio frequency signal by mixing the downconverted modulated signal with the second conversion signal.

2. A method as claimed in claim 1, wherein the common communications link comprises a free-space radio frequency transmission system.

3. A method as claimed in claim 2, wherein a carrier frequency of the transmission system is frequency modulated.

4. A method as claimed in claim 2 or 3, wherein the carrier is at microwave frequency.

5. A method as claimed in any preceding claim, wherein the conversion signal is at the same frequency as the reference oscillator and the pilot signal is derived from the reference oscillator by means of a divider.

6. A method as claimed in claim 5, wherein at the second site the conversion signal is derived from the pilot signal by means of a divider.

7. A method as claimed in claim 6, wherein a phase locked oscillator is used to derive the conversion signal from the pilot signal.

8. A method as claimed in any one of claims 1 to 4, wherein the pilot signal is at the same frequency as the reference oscillator and the conversion signal is derived from the reference oscillator by means of a multiplier.

9. A method as claimed in claim 8, wherein at the second site the conversion signal is derived from the pilot signal by means of a multiplier.

10. A method as claimed in any previous claim wherein the pilot signal is of a lower frequency than the downconverted modulated RF signal.

11. A method as claimed in any preceding claim, wherein the modulated RF signal comprises a plurality of multiplexed RF channels, each channel being suitable for use in a mobile cellular radio communications system.

12. A method as claimed in any preceding claim wherein the method also comprises the transfer of a second modulated radio frequency signal from the second site to the first site.

13. A method as claimed in claim 12 comprising the additional steps of, at the second site

deriving a third conversion signal from the pilot signal, down converting the second modulated radio frequency signal by mixing the second modulated signal with the third conversion signal,

sending the down converted second modulated radio frequency signal from the second site to the first site,

at the first site, deriving a fourth conversion signal from the reference oscillator, which fourth signal is of substantially identical frequency to the third conversion signal, and re-forming the second modulated radio frequency signal by mixing the down converted second modulated signal with the fourth conversion signal.

14. Apparatus for use at the first site in a method as claimed in any preceding claim, the apparatus comprising:

a reference oscillator,

downconverting means,

means for deriving a conversion signal from the reference oscillator for use with the downconverting means,

means for deriving a pilot signal from the reference oscillator,

and transmitting means for transmitting a RF signal.

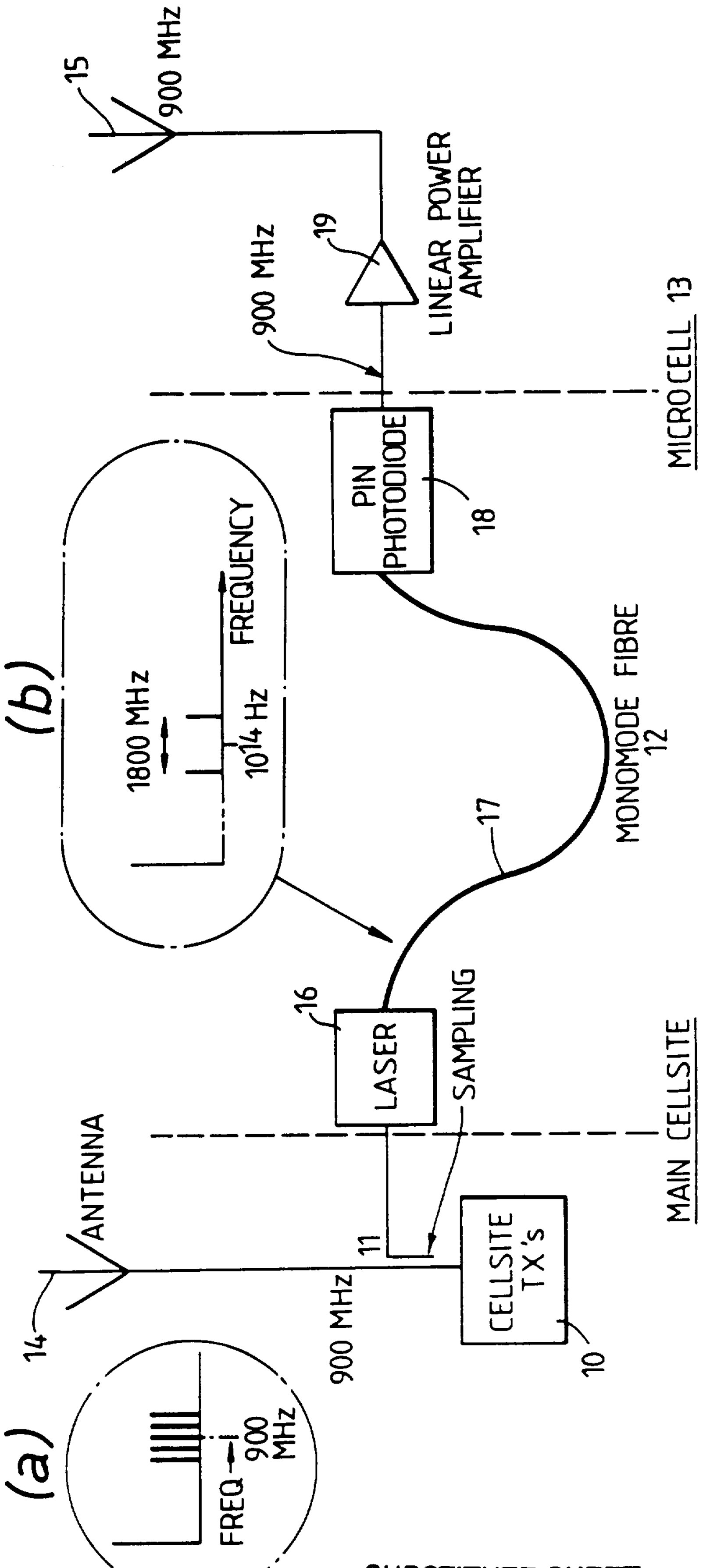
15. Apparatus for use at the second site in a method as claimed in any one of claims 1 to 11, the apparatus comprising:

receiving means for receiving a RF signal,

generating means for generating a conversion signal from a received pilot signal, and

upconverting means responsive to the conversion signal.

Fig. 1



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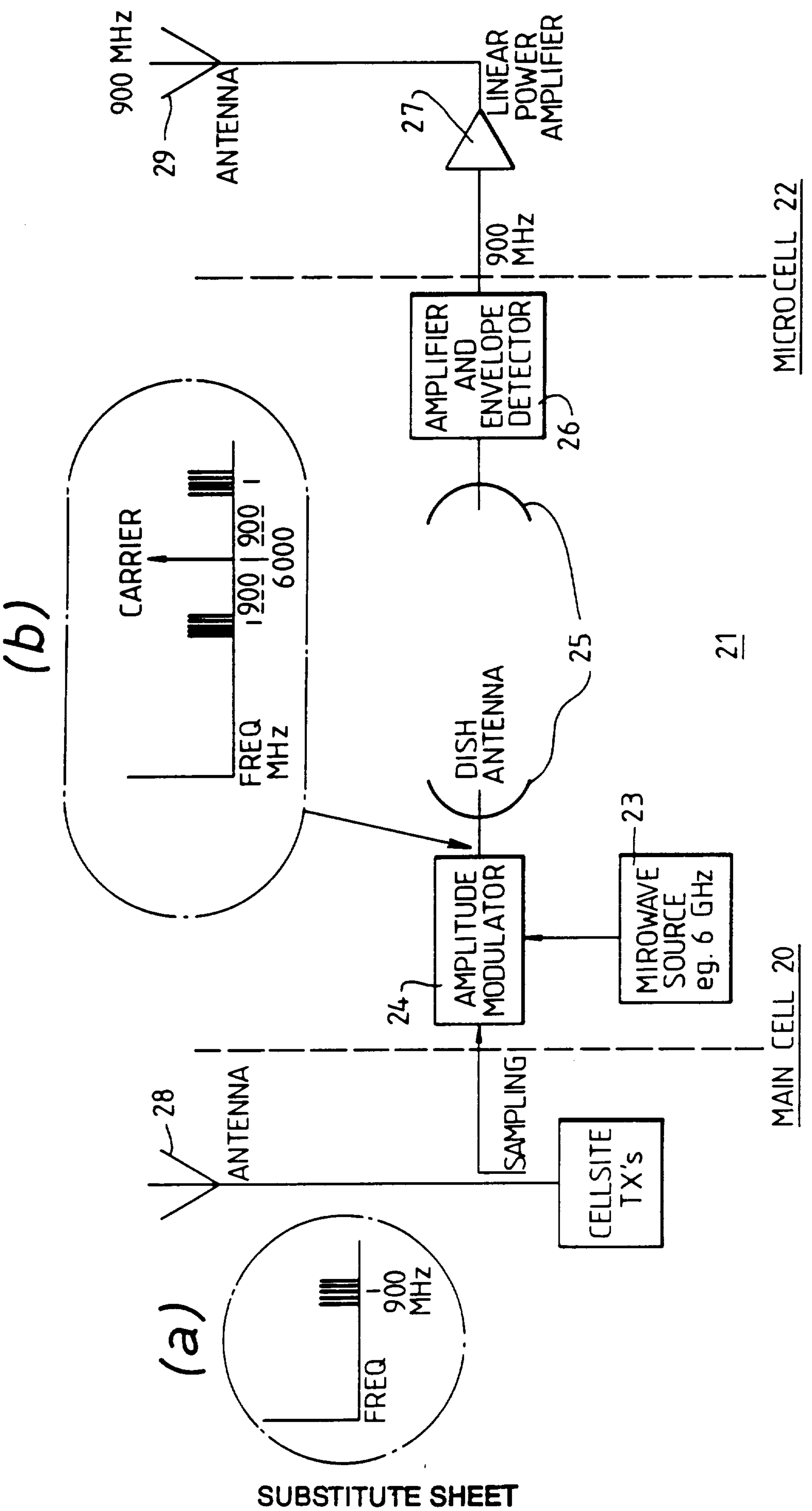
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Fig. 2

Fig. 3

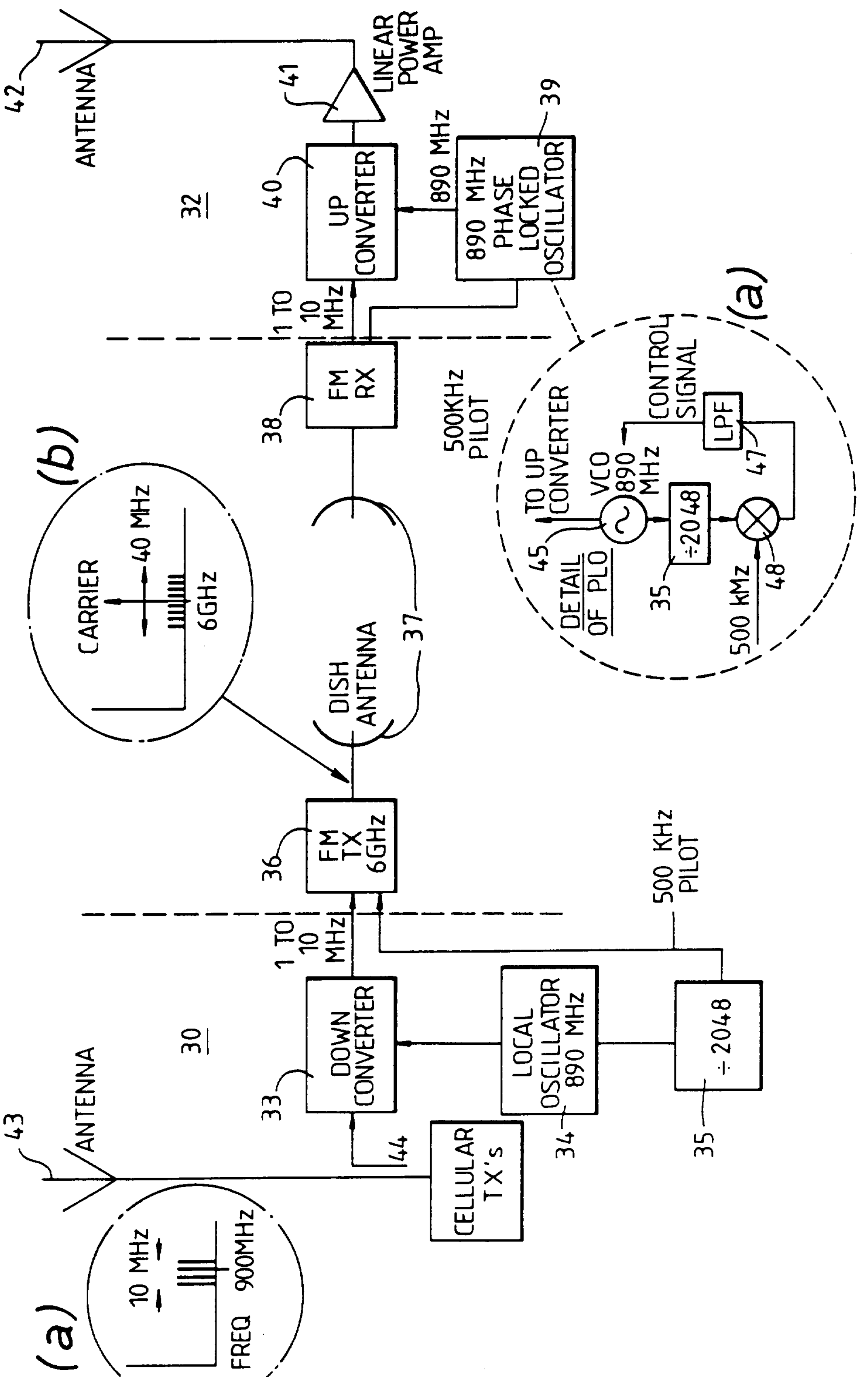

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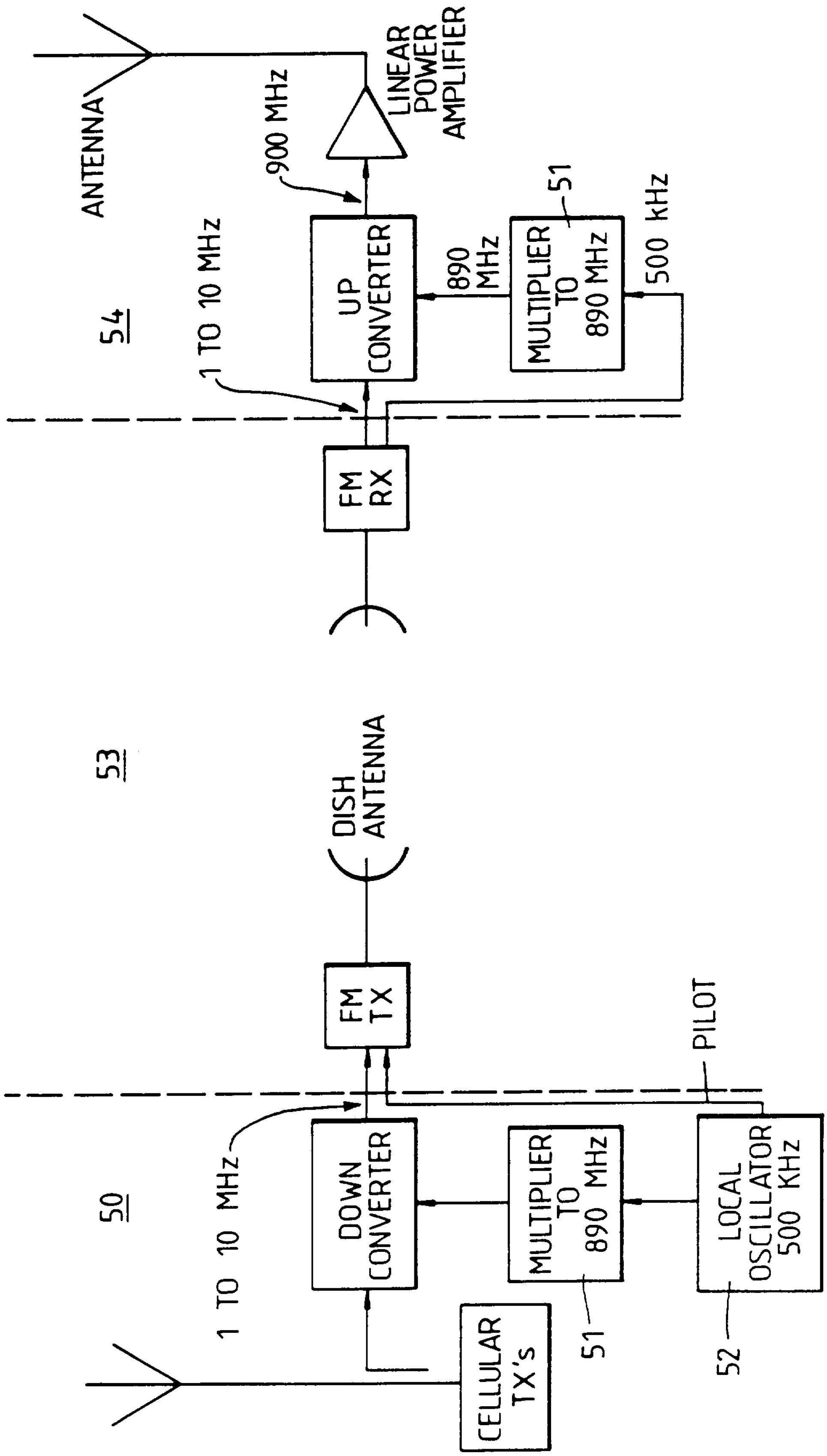
Fig. 4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INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 93/01855

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H03D3/24; H04B7/26

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Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	H03D ; H04B ; H04H

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	US,A,5 109 532 (PETROVIC ET AL) 28 April 1992 see column 1, line 37 - column 2, line 36 see column 3,. line 7 - column 3, line 21; figure 1 ---	1-7, 10-15
A	EP,A,0 468 688 (ATT) 29 January 1992 see column 5, line 30 - line 40 ---	1-4, 10-15
A	US,A,5 001 757 (FIELD ET AL) 19 March 1991 see abstract ---	1
A	EP,A,0 471 487 (HUGHES AIRCRAFT COMPANY) 19 February 1992 see figure 2 -----	8,9

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IV. CERTIFICATION

1

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
08 OCTOBER 1993	15. 10. 93
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	BISCHOF J.L.A.

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-5109532	28-04-92	None	
EP-A-0468688	29-01-92	JP-A- 4234233	21-08-92
US-A-5001757	19-03-91	None	
EP-A-0471487	19-02-92	US-A- 5221062	22-06-93
		CA-A- 2046789	17-02-92
		JP-A- 4263799	18-09-92

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