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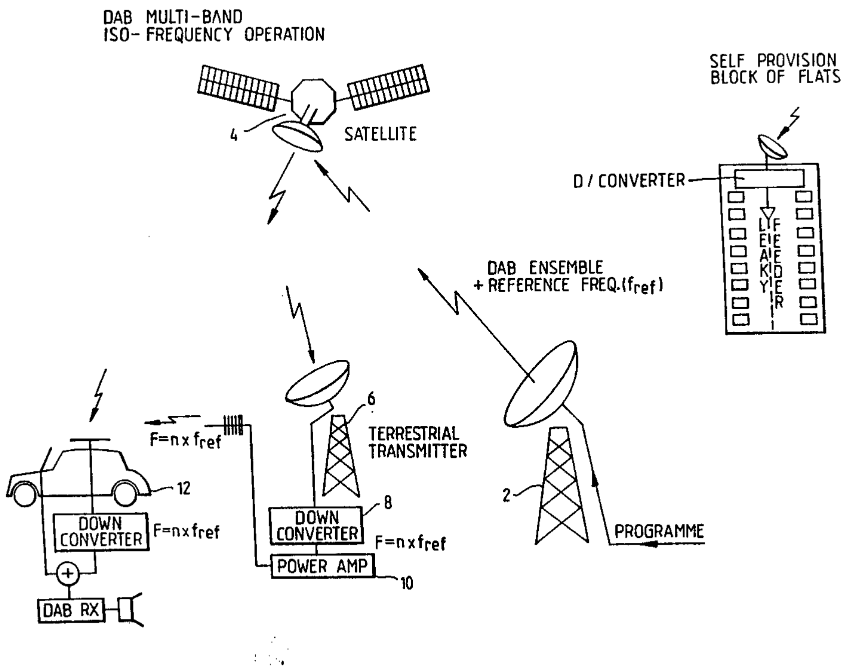
(54) Title: METHOD FOR SYNCHRONISING TRANSMITTER FREQUENCIES IN COMMON WAVE DIGITAL AUDIO BROADCAST



(57) Abstract

A digital broadcast transmission system comprises a plurality of spaced transmitters (6). Each transmitter (6) receives signals for transmission from a master transmitter (2) along with a reference frequency (F ref). The reference frequency is used to generate the transmission frequency at each transmitter. At a receiver (12) conversion means can be used to enable signals from the master transmitter and from the other transmitter to be received.

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METHOD FOR SYNCHRONISING TRANSMITTER FREQUENCIES IN COMMON WAVE DIGITAL AUDIO BROADCAST

This invention relates to digital audio broadcast systems and in particular to systems which operate by transmitting signals from a network of transmitters.

A digital audio broadcasting system is currently being developed by a consortium of European manufacturers called Eureka 147. This has proposed a coded orthoganal frequency division multiplexed (COFDM) digital audio broadcast (DAB) modulation scheme. COFDM is a wide band modulation scheme which is specifically designed to cope with problems of multipath reception. The basic idea of COFDM is to take the digital signal (data) to be transmitted and divide it between a large number of adjacent carriers and divide it between time intervals so that only a small amount of data from a sample is carried at anyone time. Error correction routines are used to correct for any errors in received signals. The carriers are arranged such that adjacent ones are mathematically orthoganal. This enables their side bands to overlap so that signals can be received without adjacent carrier interference and consequently a smaller bandwidth is necessary to transmit a plurality of carriers.

The signal is transmitted in bursts of data. Each burst is formed by distribution bits of the signal over the carriers (usually by quadrature phase shift keying) and then taking the Fast Fourier Transfer of the carriers. The resultant spectron in the modulated by a further carrier thus forming a broad band signal (DAB ENSEMBLE) for transmission. At a receiver the reverse process takes place.

In conventional AM/FM broadcasting a network of transmitters is provided. This is known as a diversity transmission system. Adjacent transmitters broadcast the same radio station on frequencies which have a sufficiently large gap between them for there to be no distortion in intermediate or "mush areas" between the transmitters. This is because there is no synchronisation of the transmission signals and therefore reception in such areas would be severely distorted if both transmitters were using the same frequency but were out of phase.

In a COFDM DAB modulation scheme each signal occupies a larger portion of the spectrum than a conventional AM/FM signal because of its division onto a plurality of carriers which are used to form comprising a "DAB ensemble". Because of this, even if signals on adjacent transmitters are spaced by the same amount as they would be in an AM/FM distribution network, there will still be interference in the intermediate or mush areas.

It has been appreciated that this problem can be overcome by synchronising the transmitters and arranging for them each to transmit identical program modulation each to use the same frequency. Using such an arrangement the signals from each transmitter will add constructively at a receiver thereby enhancing rather than degrading reception. For such operation to be successful it is essential that all the transmitters radiate substantially identical carrier frequencies and that these carriers carry identical modulation (the DAB ensemble).

The present invention is defined in the appended claims to which reference should now be made.

The invention will now be described in detail by way of example with reference to the accompanying drawings in which:

Figure 1 shows a transmission and reception system embodying the present invention;

Figure 2 shows a source transmitter for transmitting a signal to a satellite in an embodiment of the invention;

Figure 3 illustrates circuitry for use in a terrestrial transmitter embodying of the invention; and

Figure 4 shows an embodiment of the invention for use in a block of flats to improve reception.

It is proposed in a system embodying the invention that transmitters in a distribution network for DAB can be synchronised by distributing a pilot "master" frequency. This would preferably be transmitted via a satellite to all of the terrestrial transmitters along with a DAB ensemble comprising one or more program signals. A COFDM ensemble is generated at low IF frequency such as 1.5 MHz. The lowest frequency sideband would therefore be approximately 700 Khz clear of DC. This 700Khz band is known as a guard band. It is proposed that the master pilot frequency should be included in this guard band.

Figure 1 shows a transmitter 2 receiving a program signal produced by a broadcaster. It then transmits this as a DAB ensemble along with a reference frequency f_{ref} to a satellite 4. There are a plurality of terrestrial transmitters 6 which all receive a signal transmitted by the satellite 4. This signal again comprises the DAB ensemble and the reference frequency f_{ref}. The transmitter 6 locks onto f_{ref} and uses this to select a frequency F at which to make a terrestrial transmission of the DAB ensemble. F is equal to $n \times f_{ref}$. A down converter 8 and power amplifier are provided at the terrestrial transmitter for making the necessary conversion and transmission. Thus all terrestrial transmitters are sychronised to the master reference frequency f_{ref}. There is no re-broadcast of the master frequency from the terrestrial transmitters.

Receivers such as the car receiver 12 in figure 1 receive the signal transmitted by the terrestrial transmitters 6, all of which are identical. Therefore when the car receiver is in a location between two transmitters and is receiving signals from both transmitters. These identical signals add constructively and enhance reception of the signal.

A possible implementation of the source transmitter 2 of figure 1 is shown in figure 2. This comprises a COFDM modulator 16 which is phase locked by a pilot master oscillator (f_{p1}) 18 via a COFDM master 20 producing a frequency flock. One or more radio signals is modulated into a DAB ensemble by the COFDM modulator 16. The ensemble and the signal from the pilot master oscillator are then added together in adder 22 the pilot signal being included in the guard band. The combined signals are then passed through a pre-emphasis filter 24 before being FM modulated in modulator 26. A further adder 28 can be used to add a further COFDM ensemble prior to transmission.

The signal then passes through an up converter 30 before being passed to a transmitter dish 32. The optional second signal is produced in COFDM modulator 34 and can either pass via a frequency shifter 36, controlled by an offset oscillator 38, to adder 22 where it is combined with the first ensemble, or it can pass via a pre-emphasis filter 40 and a second FM modulator 42 before being combined with the output of the first modulator 26 in adder 28.

The distribution of the reference frequency and the two ensembles after passing through adder 22 is shown at 44. The possible frequency distributions after passing through adder 28 comprise two ensembles multiplexed onto one FM carrier as shown at 46 for the situation where the ensembles are combined in adder 22, or a separate FM carrier for each ensemble as shown at 48 for the situation where the ensembles are combined in adder 28.

The arrangement of the terrestrial transmitters 6 of figure 1 is shown in figure 3 and this shows a dish 50 receiving a signal from the satellite 4. The signal received passes through a dielectric resonator 52 and a down converter 54 before passing through a diplex filter 56, an FM discrimator circuit 58 and a de-emphasis filter 60. After this a signal such as the one shown at 44 in figure 2 is produced. This is passed to a diplex filter 62 which separates the DAB ensemble and the reference frequency f_{p1}. The

DAB ensemble goes to an up converter 64 and then to an amplifier 66 ready for terrestrial band III transmission.

The reference signal f_{p1} passes to a master pilot synthesiser which controls a reference oscillator 70 to produce a reference frequency signal to control the transmission frequency of an up converter 64. This happens at every terrestrial transmitter and thus each transmitter transmits a band III terrestrial signal having substantially the same phase and frequency.

An alternative arrangement is shown for the situation where a separate FM carrier is used for one of the DAB ensembles. In this the reference pilot fp2 is extracted in the diplex filter 56 and passes to a phase locked loop 72 which provides a control signal for synthesiser 74. This includes an oscillator providing a reference frequency to the down converter 54.

It is also proposed that, particularly for terrestrial transmission in the urban enviroment, both satellite and terrestrial transmitters should feed programs to receivers i.e. receivers should be dual-band. A receiver, such as a car radio receiver, would have two inputs. One of these would receive satellite band transmissions and the other the band III terrestrial signal. The receiver could include circuitry to select the best signal, in rather the same manner as an RDS (radio data system) receiver does today.

A down converter could be used in a receiver satellite aerial to generate a band III signal at the same frequency as that of the terrestrial network. Thus the signal from the down converted satellite signal can be added to that of the terrestrial signal to form a single frequency signal of the type for which DAB was designed.

The composite signal (satellite and terrestrial) may be applied to the signal aerial input of a DAB receiver thereby removing the need for any additional COFDM decoders or diversity circuitry. Receivers will thus be able to exploit the resultant signal as they move around without any degredation in performance.

The down converter and adder to combine the satellite and terrestrial signals can be provided as a bolt-on unit to modify a terrestrial DAB receiver to a dual-band DAB receiver.

In such a system the terrestrial band III relay transmitter (6 in figure 1) performs exactly the same function as the down converter provided in the receiver's antenna, except that the output power is much greater and is radiated from a fixed site for reception by remote receivers.

In order to enable down coverters (fixed or mobile) to generate band III signals at the correct frequency a pilot or reference signal is added to the DAB ensemble carried by the satellite. This signal locks oscillators of all down converters to the same frequency, thereby providing the required single frequency operation. Should the broadcaster wish to change the band III frequency used it will simply be necessary to alter the pilot or reference frequency signal transmitted.

The reference signal can be transmitted in many different ways. Here it has been described as a frequency signal transmitted in the guard band i.e. outside the DAB ensemble. There is a zero frequency carrier in the centre of the ensemble which could also be used to carry the reference signal or it could be transmitted in the synchronising interval between the DAB bursts.

The reference signal could also be transmitted as digital data which could then use some universal reference frequency available at the receiver to produce the desired frequency conversion for the DAB ensemble. This could be some inherent property of the DAB signal such as the synchronising frequency of the bursts of data.

Figure 4 shows how a down converter could be used for receiving a satellite signal in locations where terrestrial reception is poor such as a block of flats. An antenna 80 receives the satellite signal and a down converter 82 changes this to a band III signal. The band III signal is then distributed throughout the block of flats with a feeder 84.

CLAIMS

1. A digital broadcast transmission system comprising a plurality of spaced transmitters each comprising means for receiving signals for transmission and for receiving a reference signal, and means for generating a transmission frequency for a signal to be transmitted in dependence on the reference signal.

2. A digital broadcast transmission system according to claim 1 in which each transmitter generates substantially the same transmission frequency.

3. A digital broadcast transmission system according to claim 1 in which the transmission frequency generated by each transmitter has substantially the same phase as that generated by each other transmitter.

4. A digital broadcast transmission system according to claim 1, 2 or 3 in which each transmitter receives the signal for transmission and the reference signal from the same source.

5. A digital broadcast transmission system according to claim 4 in which the source is a satellite transmitter.

6. A digital broadcast transmission system according to any preceding claim in which each transmitter generates a transmission frequency which is locked to the reference signal.

7. A digital broadcast receiver comprising means for receiving a digital broadcast signal in a first frequency band and for receiving a reference signal, and means for frequency converting the digital broadcast signal to a second frequency band in dependence on the received reference signal.

8. A digital broadcast receiver according to claim 7 further including means for receiving a substantially similar second digital broadcast signal in the second frequency band.

9. A digital audio broadcast receiver according to claim 7 or 8 in which both digital broadcast signals are generated from the same source.

10. A digital audio broadcast receiver according to claim 7 and 8 in which the frequency of the frequency converted digital broadcast signal is substantially the same as the frequency of the second DAB signal.

11. A digital audio broadcast receiver according to claim 7, 8, 9 or 10 including filter means for separating first digital broadcast signal from the reference signal.

12. A dual band digital broadcast receiver comprising means for receiving a first digital broadcast signal in a first frequency band, means for receiving a second digital broadcast signal in a second frequency band, and means for converting the first DAB signal to the second frequency band.

13. A dual band digital audio broadcast receiver according to claim 12 including means for combining the second digital broadcast signal with the converted first DAB signal.

14. A dual band digital audio broadcast receiver according to claim 12 or 13 in which the first digital broadcast signal has reference information associated therewith to control the conversion of the first digital broadcast signal.

15. Apparatus for converting a single band digital broadcast receiver to a dual band digital broadcast receiver comprising means for receiving a first digital broadcast signal in a first frequency band, means for receiving a second digital broadcast signal in a

second frequency band, means for converting the first digital broadcast signal to the second frequency band, and means for combining the second digital broadcast signal with the converted first digital broadcast signal.

16. A digital audio broadcast digital broadcast transmitter comprising means for receiving a digital broadcast signal, means for receiving a reference signal and means for transmitting the DAB signal and the reference signal.

17. A digital audio broadcsast transmitter comprising means for receiving a digital broadcast signal and a reference signal and means for generating a transmission frequency for the digital broadcast signal in dependence on the reference signal.

18. A digital audio broadcast transmitter according to claim 17 in which the transmission frequency is locked to the reference frequency.

Fig. 4 SELF PROVISION BLOCK OF FLATS

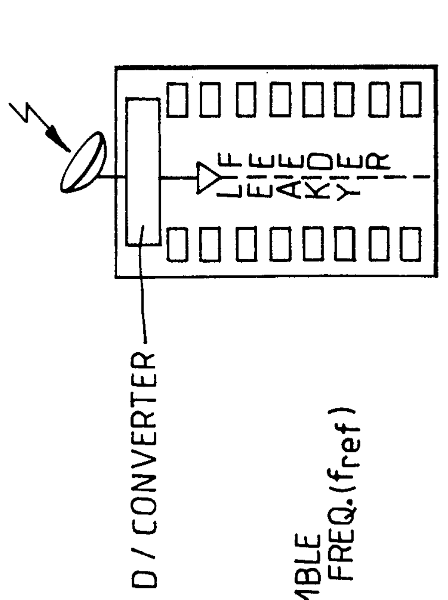

Fig. 1 DAB MULTI-BAND ISO-FREQUENCY OPERATION

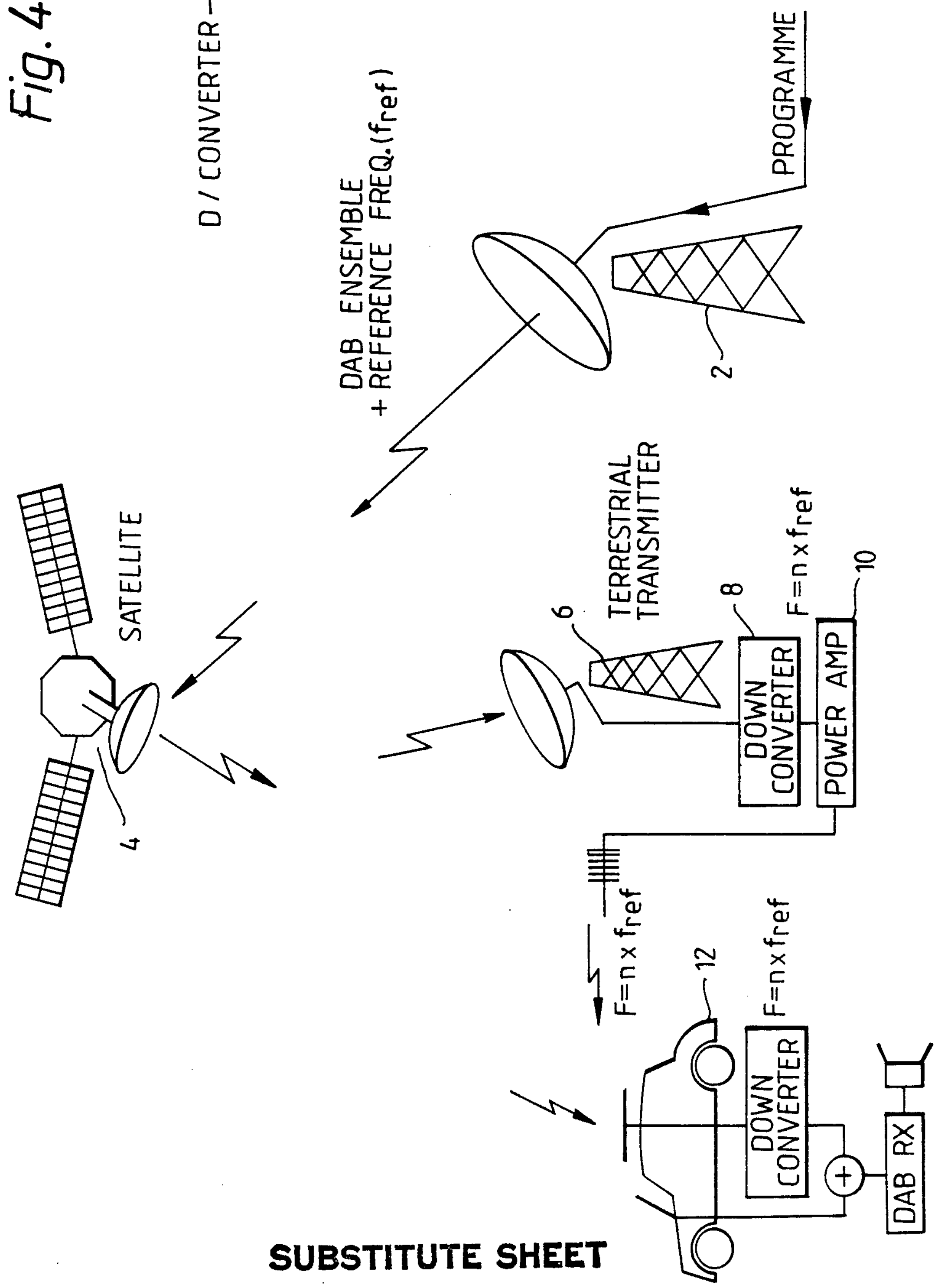

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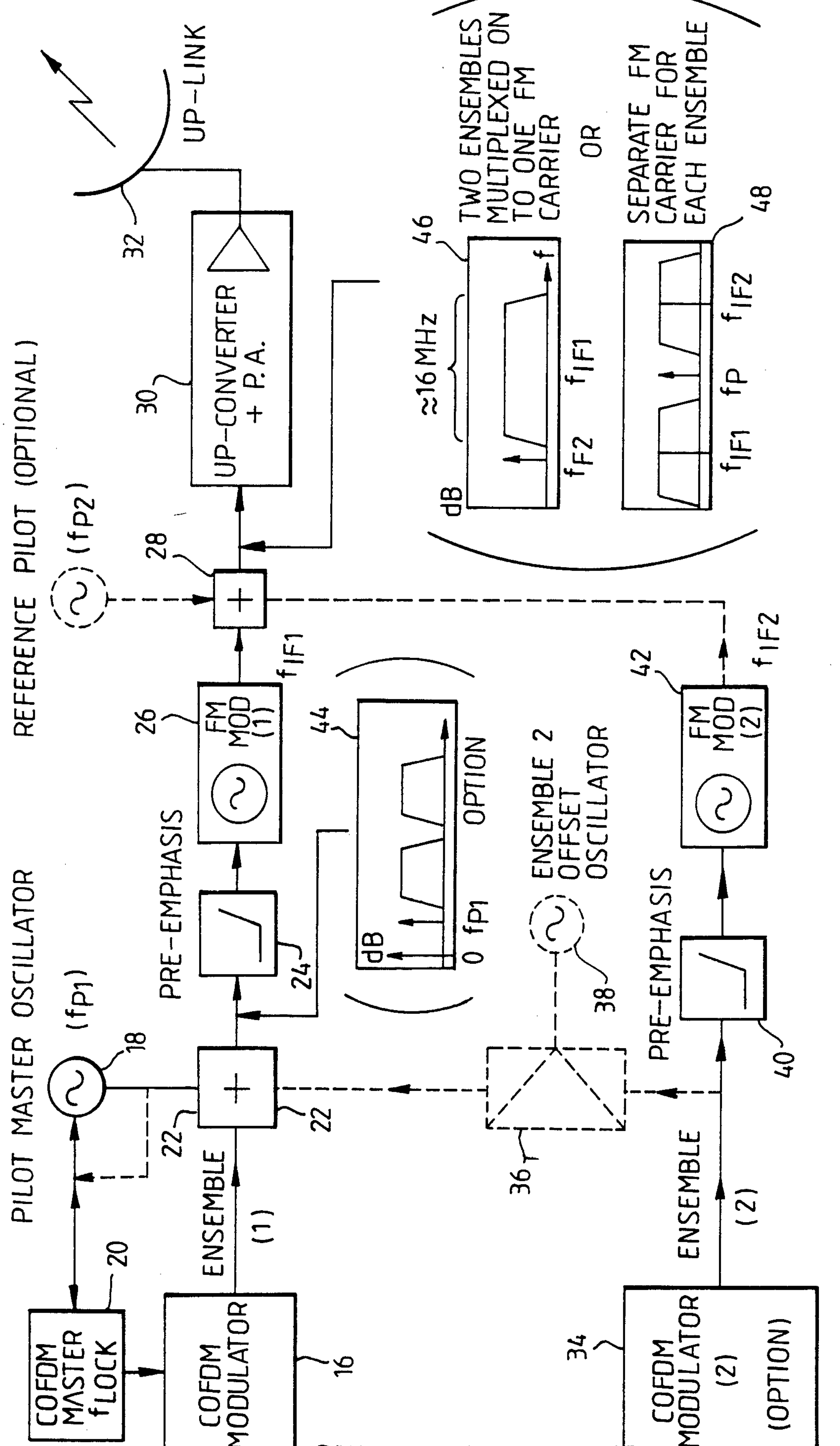
Fig. 2 POSSIBLE UP-LINK CONFIGURATIONS-DAB SATELLITE DISTRIBUTION



RECEIVER OPTIONS : PILOT TONE CARRIER REGENERATION
: DAB SATELLITE DISTRIBUTION

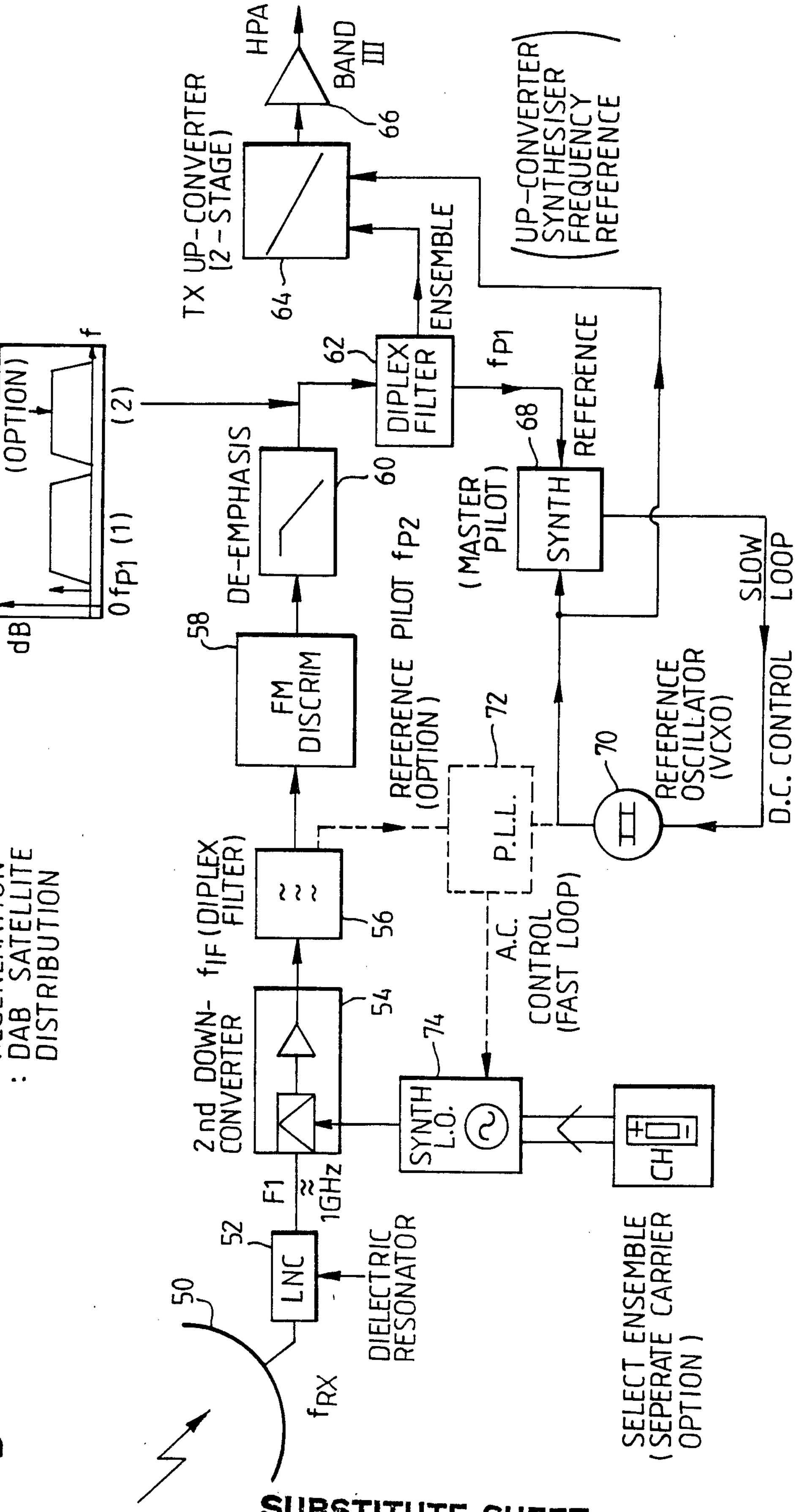


Fig. 3

INTERNATIONAL SEARCH REPORT

.al Application No
PCT/GB 93/01954

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 H04H1/00

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)
IPC 5 H04H H04B

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FERNSEH UND KINO TECHNIK vol. 45, no. 11 , 1991 , BERLIN DE pages 575 - 583 F. MÜLLER-RÖMER 'Digitale terrestrische Sendernetze für Hörfunk und Fernsehen' see page 578, column 1, line 18 - line 42; figure 5	1,7,12, 15-17
Y A	US,A,4 317 220 (MARTIN) 23 February 1982 see column 1, line 1 - column 2, line 63; claim 1; figure 3	1 2-4,6,11
Y A	EP,A,0 004 702 (MOTOROLA INC.) 17 October 1979 see page 1, line 1 - page 2, line 20; claim 1; figure 1	7,12, 15-17 14,18

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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PCT/GB 93/01954

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RUNDFUNKTECHNISCHE MITTEILUNGEN vol. 34, no. 6 , November 1990 , NORDERSTEDT DE pages 276 - 278 V.M. KOLESNIKOW, M.U. BANK 'Eine neue Konzeption für den digitalen terrestrischen Hörrundfunk' see page 276, column 2, line 7 - page 278, column 1, line 62; figures 1,2 -----	5

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Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

.nal Application No
PCT/GB 93/01954

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-4317220	23-02-82	NONE	
EP-A-0004702	17-10-79	US-A- 4188582	12-02-80
		CA-A- 1113545	01-12-81
		JP-A- 54137909	26-10-79