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(54) **Apparatus for the isofrequential broadcasting of radio programmes, particularly in frequency modulation, along a highway.**

(57) The apparatus is aimed at radio receivers on board vehicles in movement along a highway without changes in tuning, and comprises: a plurality of emitting antennae (12, 14) arranged at intervals along said highway, and respective radio-frequency amplifiers (36, 42) connected to feed said antennae; an optical fiber line (18) adjacent to said highway, fed at one end by an optical transmitter (28) driven by a radio-frequency signal to be broadcast; means (30, 38) for tapping the radio-frequency signal from the optical fiber line at each radio-frequency amplifier; and delay means (34, 40) for delaying the radio-frequency signal having their input connected to the output of said tapping means and their output connected to said radio-frequency amplifiers; the delay introduced by each of said delay means being such that in the equisignal region between every two adjacent emitting antennae the broadcast signal is substantially coherent.

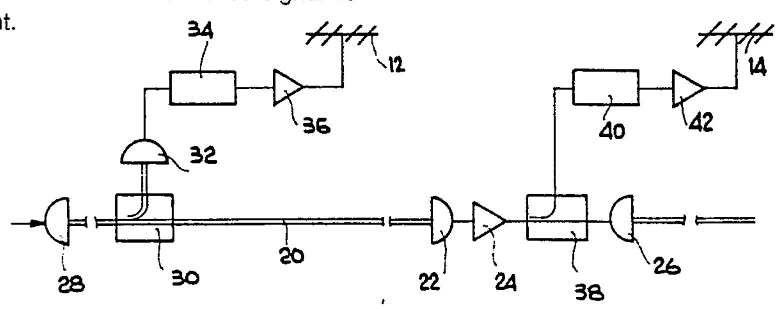

FIG. 2

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APPARATUS FOR THE ISOFREQUENTIAL BROADCASTING OF RADIO PROGRAMMES, PARTICULARLY IN FREQUENCY MODULATION, ALONG A HIGHWAY

The present invention relates to an apparatus for the the isofrequential broadcasting of radiophonic programmes, particularly in frequency modulation, along a highway, to broadcast radiophonic programmes to radio receivers located on board vehicles travelling along said highway, without the need for changes in tuning in the radio receivers.

To broadcast a same radiophonic programme to a territory greater than that irradiatable with a single emitting antenna, it is known to segment the territory into a plurality of contiguous areas, each served by a different emitting antenna, and to broadcast from the various antennae the same programme on carriers at different frequencies, the programme being transmitted to the broadcasting site for example by means of a radio link. The user tunes his receiver to the one of the nearby antennae which gives him the best reception.

The above described arrangement is satisfactory for broadcasting to domestic, and therefore stationary, radio receivers, which can be tuned once and for all to the station ensuring the best reception, while, in the case of radio receivers installed on board vehicles moving along a highway, the reception conditions are extremely variable, and would require that the receiver be tuned to a new station every few miles of travel.

If the same carrier were used for two contiguous emitting antennae in order to provide continuous reception to moving radio receivers, in the regions of overlap (equisignal regions) one would obtain an audio signal severely distorted to the point of being unrecognizable. In fact, in general the signals are broadcast from each antenna with different time delays with respect to one another, due to the different transmission and processing times which the signal is subject to with regard to each antenna, and the delays in propagation to the receiver add to said different delays. This gives rise to a deformation of the radio-frequency signal which reflects in unacceptable distortions of the signal picked up in the receiver.

To this distortion there furthermore adds another, due to another cause of spectral deformation, linked to the different depth of modulation which will occur in general in the signals broadcast by different transmitters. As is evident to the expert in the field, on the basis of the mathematical description of the frequency modulation process, a same modulating signal generates in the carrier spectral lines at different frequencies according to the depth of modulation. Thus the superimposition of the related spectra gives rise to a total spectrum with such strong anomalies as to cause severe and uncontrollable distortions of the picked up signal. The inventors have determined, on this subject, that for an acceptable reception the difference in modulation depth must be smaller than 0.2 dB, and preferably than 0.1 dB.

The aim of the invention is therefore to provide an apparatus for the broadcasting of radiophonic programmes, particularly in frequency modulation, along a highway, such as to allow the continuous reception by radio receivers on board vehicles travelling along said highway, route, without need for changes in tuning in the receiver.

The abovesaid aim is achieved by the invention, together with other objects and advantages, such as will become apparent hereinafter, with an apparatus for the isofrequential radiobroadcasting of radiophonic programmes, particularly in frequency modulation, along a highway, aimed at radio receivers in motion along said highway, characterized in that it comprises:

a) a plurality of emitting antennae arranged at intervals along said highway, and respective radio-frequency amplifiers connected to feed said antennae;

b) an optical fiber line adjacent to said highway, fed at one end by an optical transmitter driven by a radiofrequency signal to be broadcast;

c) means for tapping the radio-frequency signal from the optical fiber line at each radio-frequency amplifier; and

d) means for delaying the radio-frequency signal having their input connected to the output of said tapping means and the output connected to said radio-frequency amplifiers; the delay introduced by each of said delay means being such that in the equisignal region between every two adjacent emitting antennae the broadcast signal is substantially coherent.

A preferred embodiment of the invention will now be described, given by way of non-limitative example, with reference to the accompanying drawings, wherein:

figure 1 is a schematic view, not to scale, of a highway with distributed emitting antennae;

figure 2 is a partial block diagram of a broadcasting apparatus according to the invention;

figure 3 is a diagram of a preferred delay device used in the apparatus according to the invention.

Figure 1 shows a highway 10, with emitting antennae 12, 14, 16, arranged at intervals along the highway and having irradiation patterns with a high front-rear directivity ratio. This is indicated schematically with the preferential . lobe 11 in figure 1. In the present description and in the claims, by the expression "emitting antenna" any appropriate irradiating system is intended.

Along the highway there runs an optical fiber line 18, preferably of the monomodal type. The line 18, as will be described in greater detail hereinafter, is constituted by an optical fiber with repeaters (not shown in figure 1) inserted at intervals, intended to compensate the attenuation to which the signal which runs in the fiber is subject, typically of the order of 0.5 dB per kilometer of line. In the continuation of the description and in the claims, the expression "optical fiber line" refers to said line, including all the repeaters along it, in a per se known manner. The emitting antennae 12, 14, 16 are fed with signals tapped from the line 18, as will be described in greater detail hereinafter.

In figure 2, a portion of line 18 is illustrated, constituted by an optical fiber 20, with a repeater, illustrated by way of example, comprising an optical receiver 22, for example of the PINFET type, per se known, adapted to demodulate the signal carried on the optical signal in the fiber to obtain an electric signal, an amplifier 24 adapted to amplify said electric signal obtained from the demodulation, and a laser transmitter 26, also per se known, adapted to receive the amplified electric signal and to modulate it on an optical carrier which is introduced in the fiber. The optical fiber line comprises several repeaters of this type, distributed along the line at intervals which depend on the attenuation of the fiber, as is known in the field.

The head of the line 18 is fed by an initial optical transmitter 28, which is driven by the radio-frequency signal to be transmitted, for example a 100 MHz signal with maximum modulation deviation of ± 75 KHz, and modulates it on an optical carrier in a per se known manner.

To tap the signal at the emitting antennae, optical couplers are furthermore inserted in the optical fiber line. One coupler is shown by way of example at 30, to tap a fraction of the optical power flowing in the fiber and to apply it to an optical receiver 32, similar to receiver 22. The electric output signal of optical receiver 32, which is the radio-frequency signal to be transmitted, is delayed by a predetermined time delay, described hereinafter, in a delay device 34, also described hereinafter. The delayed radio-frequency signal which leaves the delay device 34 is applied to a radio-frequency amplifier 36, which feeds the emitting antenna 12.

Where the emitting antenna is near to an optical repeater, the signal is preferably tapped from the line by a hybrid coupler 38 inserted downstream with respect to the radio-frequency amplifier 24. The signal thus tapped, which is the radio-frequency signal, is applied to a delay device 40, from which it goes to a radio-frequency power amplifier 42 which feeds the emitting antenna 14.

According to the invention, in order to provide an intelligible reception even in the regions of overlap between the portions of irradiation of two adjacent antennae (that is to say in the regions in which the intensities of the signals of one of the two antennae is not negligible with respect to other), the transmission of the two antennae is made coherent by appropriately calibrating the delays introduced in the feeds to said antennae. More exactly, if T1 is the time required by the signal to travel through the portion of optical fiber line between two adjacent antennae, T2 is the time of propagation from the antenna upstream with respect to the equisignal region, and T3 is the propagation time from the antenna downstream with respect to the equisignal region with the signal of the upstream antenna, the delays R1 and R2 introduced by the delay devices of the upstream antenna and of the downstream antenna must meet the relation:

$$R1 + T2 = T1 + R2 + T3.$$

By writing a similar relation for all the antennae in succession, and imposing furthermore an arbitrary value, generally nil, for the delay for the last antenna, at the end of the optical fiber line, the delay for all the antennae are determined, and are found to be increasing from the last antenna going upstream towards the first.

A vehicle equipped with a radioreceiver, and moving along the highway between one antenna and the next one, will first receive in a prevalent manner the signal of a single antenna. When the signal of the other antenna also becomes appreciable, the two signals, due to what has been described above, will be substantially coherent, and reception will still be good. Finally the vehicle will definitely enter the field of the second antenna, while the signal of the first one will become negligible. This situation repeats for all the successive antennae, and in practice the radio receiver on board the vehicle will have continuous reception despite its movements.

Since a copy of the same radio-frequency signal, that is to say of the same modulated electric carrier, is fed to all the emitting antennae, it is evident that the condition described in the introduction, i.e. that the difference in modulation depth among the carriers irradiated by different antennae be contained within 0.2 dB, or preferably 0.1 dB, is certainly met.

Furthermore, the inventors have determined, from practical tests, that the difference in delay of the modulation in critical points must be preferably smaller than 5 usec. This condition can be met by adjusting the delays of the signal at the various antennae as described above.

As described above, each emitting antenna has a high front-rear directivity ratio in a direction longitudinal to the highway. This not only has the purpose of limiting the power to be irradiated, for a given service level on the highway, but most of all, according to the invention, said directivity reduces the extension of the region of confusion between the signals of two successive antennae, that is to say of the region where the intensities of the two signals are comparable, and therefore the picked up signal is more distorted. In fact if the antennae are isotropic, the overlap region is equidistant from the two antennae, with gradients of intensity of the signals which cross with low inclination. Thus the two signals have an approximately equal intensity for a long region. Instead, by imparting high front-rear ratios to the antennae, the intensity gradient of the signal received rearwards is very steep, and said signal rapidly becomes negligible with respect to the other. Thus the overlap region is much less extended.

The delays introduced by the several delay devices are heavily variable, ranging from 0 to a few hundred microseconds. A delay device of this type can be provided for example with surface wave devices. With reference to figure 3, a particularly versatile embodiment of a delay device according to the invention, employing digital methods, will now be described.

With reference to figure 3, the delay device comprises a frequency converter 50 which converts the RF signal at 2 MHZ. The 2 MHz signal is sampled at a 5-MHz rate and applied to an analogic/digital converter 52, to supply, again at a 5 MHz rate, 8-bit words which are alternately written by a write circuit 54 in successive addresses of one or the other of two RAM memories 56 and 58. A read circuit 60 alternately reads one word from one of the two memories 56 and 58, again at a 5 MHz rate, every time from an address backspaced by a desired offset with respect to the current write address. The offset is chosen so that the readout always occurs on the one of the memories 56 and 58 on which writing is not occurring, so as to avoid disastrous interferences. The words read in succession are applied to a digital/analogic converter 62, the output whereof, after filtering (not shown), is reconverted in frequency in a converter 64 to reobtain a radio-frequency signal which is a replica of the signal in input to the converter 50, delayed by a time which depends on the offset in the readout of the memories 56 and 58 by the read circuit 60.

Since the offset may be varied within arbitrary limits, depending only on the size of the memories, it is possible to obtain arbitrary delays of the RF signal.

According to a further advantageous development of the invention, if the highway comprises tunnels, broadcasting in the tunnel occurs by arranging along the ceiling of the tunnel a slit cable or similar leaking cable, according to known methods. The slit cable is to be considered, for the purposes of the invention, as a particular type of emitting antenna, to which the same feeding rules described above are applied. In particular, the cable will be fed at its input as described with reference to figure 2, and the same considerations on signal delays, both with reference to the antenna immediately preceding the beginning of the tunnel and with reference to the successive antenna at the exit of the tunnel, are valid therefor, it being evident that, to cover the portion of highway at the exit from the tunnel, an emitting antenna, also subject to the same rules described above, must be prearranged immediately adjacent to the exit of the tunnel.

A preferred embodiment of the invention has been described, but naturally it is susceptible of equivalent modifications and variations, obvious for the expert in the field according to the given teachings, without thereby abandoning the scope of the inventive concept.

Claims

1. Apparatus for the isofrequential broadcasting of radiophonic programmes, particularly in frequency modulation, along a highway (10), aimed at radio receivers in motion along said highway, characterized in that it comprises:

a) a plurality of emitting antennae (12, 14) arranged at intervals along said highway, and respective radio-frequency amplifiers (36; 42) connected to feed said antennae;

b) an optical fiber line (18) adjacent to said highway, fed at one end by an optical transmitter (28) driven by a radio-frequency signal to be broadcast;

c) tapping (30; 38) means for tapping the radio-frequency signal from the optical fiber line at each radio-frequency amplifier; and

d) delay means (34; 40) for delaying the radio-frequency signal, having their input connected to the output of said tapping means and their output connected to said radio-frequency amplifiers; the delay introduced by each of said delay means being such that in the equisignal region between every two adjacent emitting antennae the broadcast signal is substantially coherent.

2. The broadcasting apparatus according to claim 1, characterized in that said tapping means for at least one of said emitting antennae consist of an optical coupler (30) inserted in series in the

optical fiber line and having its derived output connected to an optical receiver (32) which drives said delay device.

3. The broadcasting apparatus according to claim 1, characterized in that said tapping means for at least one of said emitting antennae consist of the arrangement in series of an optical receiver, (22) an amplifier (24), a hybrid coupler (38) and an optical transmitter (26), the derived output of the hybrid coupler driving the delay means.

4. A broadcasting apparatus according to one of claims 1-3, characterized in that each of said emitting antennae has a high ratio of front-rear directivity in a direction longitudinal to the highway.

5. A broadcasting apparatus according to one of claims 1-3, characterized in that, where the highway extends in a tunnel, the apparatus comprises an emitting antenna constituted by a slit cable which runs along the ceiling of the gallery, and fed by said tapping means at its entrance.

6. A broadcasting apparatus according to one of claims 1-5, characterized in that each of said delay means comprises:

a) circuit means (50, 52) for sampling and converting the signal into digital words;

b) memory means (56, 58);

c) means (54) for writing said digital words in succession in successive addresses of said memory means;

d) means (60) for reading said words from successive addresses of said memory means, offset by a desired offset with respect to the write addresses;

e) means (62, 64) for the conversion of said words read by the readout means into analogic form.

7. A broadcasting apparatus according to claim 6, characterized in that said memory means comprise two memories, said write and readout means being adapted to write and read alternately therefrom.

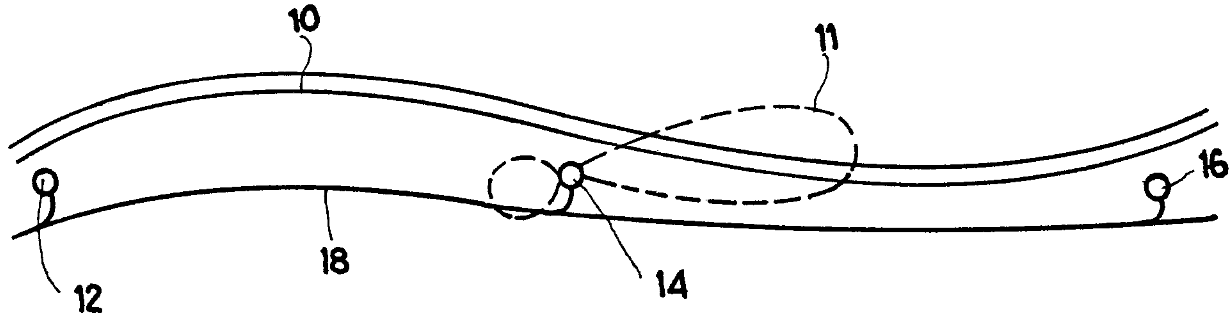

FIG. 1

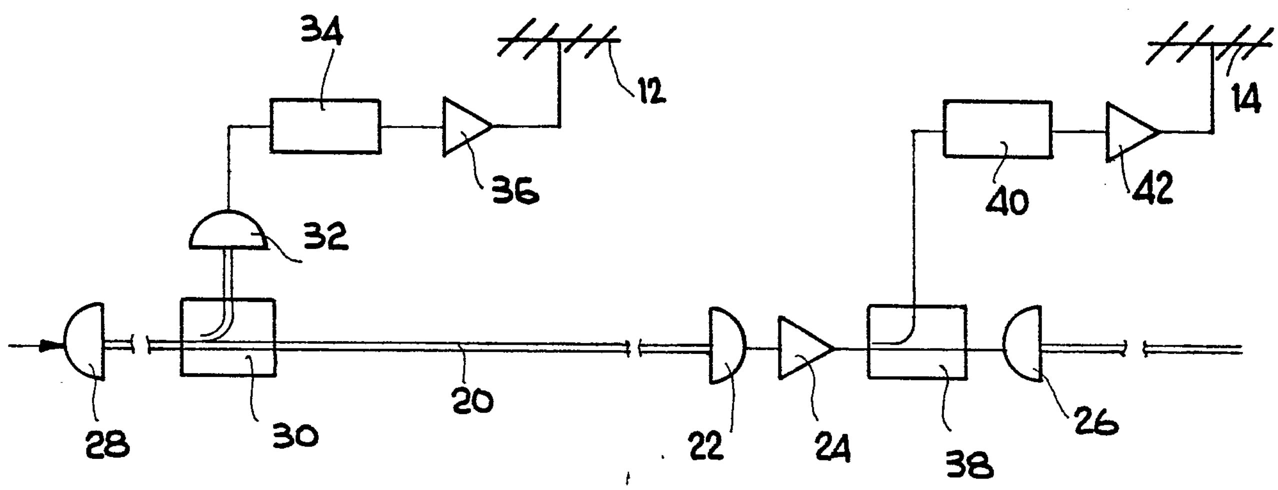

FIG. 2

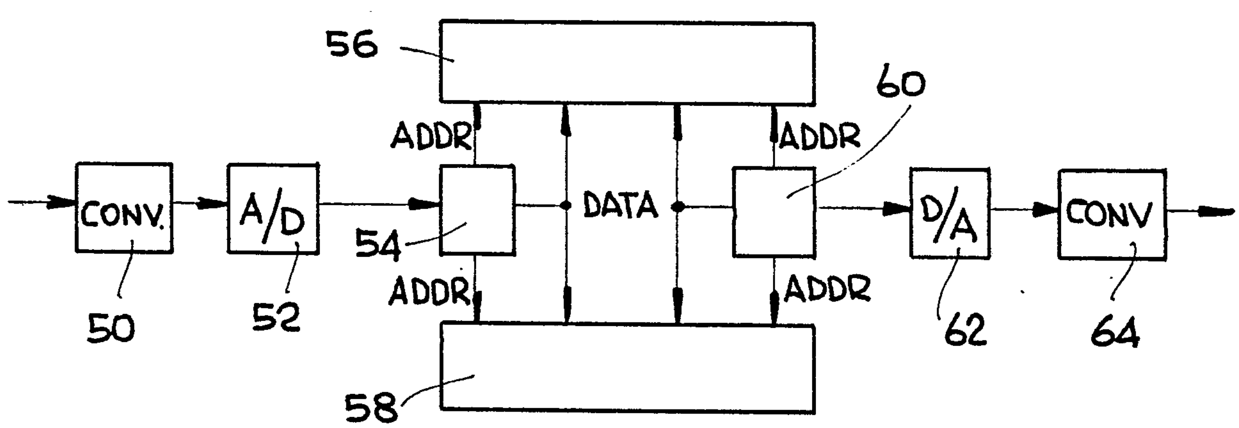

FIG. 3