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TITLE**A Network For Broadcasting A Digital Signal****FIELD OF THE INVENTION**

This invention relates to a network for broadcasting over a desired coverage
5 area a digital signal. The digital signal can be of any desired content, however
the invention is described in relation to digital television (TV).

BACKGROUND ART

Historically, where analog TV signals are difficult to receive, it has been
common practice to re-transmit signals onto another frequency using a filler
10 station. This technique is referred to as the gap filler technique, and is
commonly used throughout the world. However, this is an inefficient use of
available bandwidth because the filler station cannot retransmit the TV signal on
the same frequency as the original signal. Since most areas are able to receive
multiple TV signals, each of these TV signals must be rebroadcast on separate
15 frequencies by the filler station, resulting in the frequency spectrum available for
TV signal broadcasts in any particular area to be used. This is termed spectrum
inefficiency.

Accordingly, it is desirable for a single TV signal to be able to be delivered
throughout an entire service area on a single frequency. In areas where the
20 signals are difficult to receive, this may necessitate broadcasting the same
signal on multiple transmitters. As a result, it is also desirable when in an area
where reception from two or more transmitters is possible, that the signals from
each of the transmitters don't destroy or interfere with each other. =

Recently, there has been an increasing move towards digital TV, whereby TV
25 signals are sent in digital form. A characteristic included in many proposed



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digital transmission systems for digital television is referred to as a guard interval. The guard interval is a quiet time after each symbol where no signal is transmitted. The guard interval is intended to allow receivers to have time to process reflected signals so that the reflected signals do not combine with the subsequent symbol and cause inter-symbol interference. Thus, the guard interval is intended to avoid the ghosting phenomenon experienced by analogue TV signals where reflected signals are present.

SUMMARY OF THE INVENTION

In accordance with one aspect of this invention, there is provided a network for broadcasting over a desired coverage area a digital signal having a guard interval, said digital signal provided at a source, said network comprising: means for communicating said digital signal to a plurality of transmit stations, each transmit station comprising synchronisation means, modulation means and a transmitter, whereby said synchronisation means are arranged such that said digital signal is transmitted from all transmit stations simultaneously, and said guard interval is of a length sufficient to avoid inter-symbol interference within the desired coverage area arising from signals broadcast from the transmit stations.

Preferably, said synchronisation means includes delay means arranged to delay transmission of said digital signal, to compensate for delays in communicating the digital signal from the source to the transmitter.

Preferably, the delay means includes a buffer. More preferably, said buffer is a fifo buffer.

Preferably, said buffer is capable of buffering the digital signal for the maximum communication delay experienced by the means for communicating the digital signal to the transmitters.

Preferably, said buffer is of the size:

$$\frac{\text{longest communication delay}}{\text{signal rate}} + 1 \text{ symbols of the digital signal.}$$

Preferably, each delay means introduces a prescribed delay according to the difference between the transmit station receiving the digital signal and the
5 maximum communication delay.

Preferably, the synchronisation means includes clocking means arranged to control the rate of propagation of the digital signal through the buffer.

Preferably, the clocking means comprises a signal received from a global positioning satellite. Alternatively, said clocking means comprises a time stamp
10 encoded in the digital signal.

Preferably, the prescribed delay at the transmit station experiencing the longest communication delay is set to 1, and the prescribed delays for other transmitters are calculated therefrom.

BRIEF DESCRIPTION OF THE DRAWINGS

15 This invention will now be described with reference to one embodiment thereof in the accompanying drawings; in which:

Figure 1 shows a network for broadcasting a digital signal in accordance with the embodiment of the invention;

Figure 2 shows the synchronisation circuit of the embodiment; and

20 Figure 3 shows an arrangement of transmit stations to provide coverage to a desired area.

The embodiment relates to a network 10 for broadcasting over a desired coverage area a digital signal having a guard interval. Although the embodiment will be described with reference to the digital signal being a digital TV signal, it should be appreciated that the invention is applicable to
5 broadcasting digital signals carrying any form of information content.

The digital signal originates from a source 12. In the embodiment, the source 12 is an output of a television station prior to modulation and transmission. The digital signal may be formatted and/or encoded in a variety of different ways, such as the output of a NEWS DATA SYSTEM series 3000 coder, which outputs
10 coded MPEG-2 pictures and digital MPEG-2 audio in what is called a DVB transport stream.

The network 10 comprises a high speed link 14 and a plurality of transmit stations 16. The digital signal is communicated to each of the transmit stations 16 from the source 12 via the high speed link 14. The bandwidth of the high
15 speed link 14 must be at least what is required to transmit the digital signal, which is 40 Mbit/second for one transport stream of current digital TV signals. The link 14 can take any suitable form, such as a fibreoptic cable or a microwave link. For the purposes of the invention, the link 14 is a means for communicating the digital signal to each of the transmit stations 16, albeit at
20 slightly different delayed time intervals.

Each transmit station 16 comprises a synchronisation circuit 18, a modulator 20 and a transmitter 22 including an antenna 24. The digital signal received via the high speed link 14 at each transmitter 16 is input to the synchronisation circuit 18. The signal output from the synchronisation circuit 18 is input to the
25 modulator 20, which modulates the digital signal about an intermediate frequency in accordance with the required broadcast standards and requirements. The modulated signal is input to the transmitter 22 whereupon it is broadcast via the antenna 24.

Each transmit station 16 transmits the modulated signal on the same frequency. Accordingly, the network 10 is spectrally efficient, with the digital signal being broadcast to the desired coverage area on a single frequency.

The synchronisation circuit 18 in each transmit station 16 acts to ensure that all of the transmit stations 16 are transmitting the digital signal simultaneously. The synchronisation circuit 18 is shown in detail in Figure 2.

Each synchronisation circuit 18 comprises a fifo buffer 26, a programmable delay 28 and a global positioning satellite (GPS) receiver 30. The GPS receiver 30 is arranged to receive a clock signal from a GPS satellite which is input to the programmable delay 28. The programmable delay 28 introduces a pre-programmed delay, after which the clock signal is forwarded to the output clock of the fifo buffer 26.

The fifo buffer 26 must be capable of buffering a sufficient number of symbols of the digital signal to accommodate the delays introduced by the very high speed link 14. If the maximum delay introduced by the high speed link 14 is D_{link} seconds, then each fifo buffer 26 must be capable of buffering D_{link} seconds worth of the digital signal. For instance, if the digital signal has a symbol rate of one every S_{rate} seconds, the size of the fifo buffer 26 must be $\frac{D_{link}}{S_{rate}} + 1$ symbols.

The additional '1' in the size of the fifo buffer 26 is to allow the transmit station 16 which is subject to the greatest delay to be buffered and thus still be synchronised with the other transmit stations 16.

As information is received from the high speed link 14, it is stored in the fifo buffer 26. The digital signal is output from the fifo buffer 26 and the synchronisation circuit 18 upon receipt of clock signals from the programmable delay 28 and the GPS receiver 30. The programmable delay 28 in the synchronisation circuit 18 of each transmit station 16 is programmed to provide a delay to compensate for the delays introduced by the high speed link 14 so

that the same symbol of the digital signal will be output from each synchronisation circuit 18 of all of the transmit stations 16 simultaneously. This is described in further detail below.

All of the programmable delays 28 are determined with respect to the transmit station 16 experiencing the greatest delays.

For example, assuming that the maximum delay introduced by the high speed link 14 is 10 microseconds, and the digital signal produces 1 symbol every microsecond, the size of the fifo buffer 26 must be $10/1 + 1 = 11$. Assuming that the network consists of five transmit stations 16, located at delays of 0, 3, 5, 8 and 10 from the source 12, the delays of the programmable delay 28 are set as follows:

the transmitter experiencing a delay of 10 from the source 12 has the programmable delay 28 set to be 1 symbol time (in this example 1 microsecond);

15 the transmitter experiencing a delay of 8 from the source 12 has the programmable delay 28 set to be 3 symbol times;

the transmitter experiencing a delay of 5 from the source 12 has the programmable delay 28 set to be 6 symbol times;

20 the transmitter experiencing a delay of 3 from the source 12 has the programmable delay 28 set to be 8 symbol times;

the transmitter experiencing a delay of 0 from the source 12 has the programmable delay 28 set to be 11 units.

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Accordingly, the delay introduced by the programmable delay 28 in each synchronisation circuit 18 compensates for the delays introduced by the high

speed link 14 from the source 12 to each transmit station 16 so that each transmit station 16 transmit the same symbol of the digital signal simultaneously.

It is to be noted that the programmable delay 28 of the furthestmost transmit station 16 has its delay set to be 1 rather than 0, otherwise this transmit station 5 16 would not be synchronised relative to the other transmit stations.

In this embodiment, the clock has been described as being from a GPS satellite, however other arrangements are possible. For instance, the Japanese ISDB-TV system has a provision whereby a time stamp can be inserted in the digital signal. According, it will be possible to add in a code representing the GPS time 10 to the digital signal and have each synchronisation circuit 18 decode this time and use it as a reference by comparing the code with the received satellite reference time signal. If this implementation were to be adopted, there would be no need for a delay of 1 at the further most transmit station 16, since each symbol of the digital signal is synchronised by the time signal in the digital signal 15 and the external satellite time. However, the provision of a time stamp within the digital signal can become inefficient.

In most practical implementations, multiple transmit stations 16 are required in order to provide complete coverage of a desired area. This is because of the presence of buildings, hills and other objects which may partially obscure the 20 desired area from a single transmit station 16.

Figure 3 shows a simplified diagrammatic representation of three transmit stations 16, each arranged to broadcast the digital signal over the desired coverage area 32. With the transmit stations 16 arranged as described above, each transmit station 16 will transmit the digital signal simultaneously. However, 25 the signal from each transmit station 16 may be received at different times at varying locations within the desired coverage area 32. In order to avoid the possibility of intersymbol interference, the guard interval of the digital signal is chosen to be at least equal to the maximum delay between signals from any two

of the transmit stations 16 being received in the desired coverage area. Accordingly, although a receiver within the desired coverage area 32 will not receive signals from the transmit stations 16 necessarily simultaneously, each symbol in the digital signal will arrive at the receiver from all of the transmit
5 stations 16 prior to the receiver receiving the next symbol from any of the transmit stations 16.

The above arrangement also assists in overcoming Doppler effects caused from mobile receivers. Accordingly, the present invention is well suited to delivering digital signals to mobile receivers.

- 10 In addition to the benefits described above, the present invention retains the advantage of the guard interval providing some immunity to ghosting from reflected signals.

It should be appreciated that the scope of this invention is not limited to the particular embodiment described above.

CLAIMS

1. A network for broadcasting over a desired coverage area a digital signal having a guard interval, said digital signal provided at a source, said network comprising: means for communicating said digital signal to a plurality of transmit stations, each transmit station comprising synchronisation means, modulation means and a transmitter, wherein said synchronisation means comprises a buffer, clocking means coupled to the buffer and arranged to control the rate of propagation of the digital signal through the buffer, and delay means operable to introduce a prescribed delay to the clock signal input to the buffer according to the difference between the delay at the transmit station receiving the digital signal and the maximum communication delay, such that the digital signal is transmitted from all transmit stations simultaneously.
2. A network as claimed in claim 1, wherein said buffer is a fifo buffer.
3. A network as claimed in claim 1 or 2, wherein said buffer is capable of buffering the digital signal for the maximum communication delay experienced by the means for communicating the digital signal to the transmitters.
4. A network as claimed in any one of claims 1 to 3, wherein said buffer is of the size: $\frac{\text{longest communication delay}}{\text{signal rate}} + 1$ symbols of the digital signal.
5. A network as claimed in any preceding claim, wherein the clocking means comprises a signal received from a global positioning satellite.
6. A network as claimed in any one of claims 1 to 4, wherein said clocking means comprises a time stamp encoded in the digital signal.
7. A network as claimed in any preceding claim, wherein the prescribed delay at the transmit station experiencing the longest communication delay is set to 1, and the prescribed delays for other transmit stations are calculated therefrom.