

VSF ENCODER AND RF MODULATOR FOR DIGITAL TELEVISION RECEIVER**Background of the Invention and Prior Art**

This invention relates generally to digital VSB (vestigial side band) television receivers and specifically to a simple low cost system for coupling a digital VSB signal from any of a plurality of sources of MPEG (Motion Picture Experts Group) digital signal to a digital VSB television receiver. While the description is directed to a VSB digital format, it should be understood that the invention in its broader aspects is not limited to a particular digital format.

The recently adopted Digital Television Standard specifies a VSB subsystem having a terrestrial broadcast mode (8VSB) and a high data rate mode (16 VSB). There are other VSB modes available, namely 2 VSB, 4 VSB and 8 VSB (non terrestrial). The 8 VSB terrestrial mode has the data carrying capability of 4 VSB. (The Trellis coding that is added for the terrestrial environment creates the additional modulation levels.) The digital data signal is MPEG and Dolby AC-3 processed and must be subjected to decompression before application to conventional video and audio circuitry. For terrestrial broadcasting, the data signal is: randomized; subjected to Reed-Solomon (R/S) type encoding for error correction; interleaved; Trellis encoded; multiplexed with segment sync and field sync; supplied with a DC pilot; subject to pre-equalization filtering; modulated; and RF upconverted for transmission. The digital television receiver includes a tuner and a VSB demodulator for developing the baseband signal, which is in compressed form. The demodulated signal is applied to an equalizer for equalizing the received signal. The baseband signal is applied to a transport demultiplexer which directs the data to an appropriate MPEG decoder and a Dolby decoder for recovering the video and audio in proper form for application to video and audio processing circuitry. Digital signals from other sources, such as DVD (digital video disk) players, VCRs (video cassette recorders), PCs (personal computers), digital cable boxes, satellite receivers and the like will be supplied to

digital television receivers, as is the case for present analog television receivers.

In an analog system, it is well known that coupling the signal from a VCR or other video source to a baseband input of a television receiver (if one is available) yields superior results than those achieved by modulating the signal to RF channel 3 or channel 4 and supplying it to the tuner input of the television receiver. This is not, however, necessarily true in a digital environment in which case the distance between the baseband signal source and the television receiver must be kept relatively short.

In accordance with the invention, a compressed baseband digital signal is encoded in a given format for digital transmission and modulated on an RF carrier for direct application via a cable network or wireless link to the RF input of a digital television receiver. The RF signal, which is at a low power level and has a less-than-nominal bandpass, takes advantage of the front-end signal processing that is built into the digital television receiver. Signal impairments, due to the less-than-nominal bandpass characteristic and noise introduced during transmission, that are below a given threshold are corrected by the correction circuitry in the digital television receiver front end. The low signal power, the corrective circuitry for the digital signal and the benign environment of the communications link, enable components and circuits of much lower tolerance (and cost) to be used in the encoding and modulating process. The result is an encoder-modulator that is very low cost and very effective in coupling a digital baseband signal to a digital television receiver over an RF channel.

Objects of the Invention

A principal object of the invention is to provide a novel digital signal translation system.

Another object of the invention is to provide a digital encoder-modulator for coupling a baseband digital signal to a VSB digital television receiver.

A further object of the invention is to provide a low cost digital signal coupling system for a VSB digital television receiver.

Brief Description of the Drawings

These and other objects and advantages of the invention will be apparent upon reading the following description in conjunction with the drawing, in which:

FIG 1 is a simplified block diagram of a VSB digital signal encoder-modulator constructed in accordance with the invention;

FIG 2 is a simplified block diagram of another form of a digital signal encoder-modulator constructed in accordance with the invention; and

FIG 3 are curves illustrating the bandpass characteristics of the encoder-modulator of the invention.

Description of the Preferred Embodiment

Referring to FIG 1, a source of digital MPEG encoded signal 10 derived from any of a number of different source types, is shown. For example, the source may comprise a satellite receiver, a VCR, a DVD, a digital cable box, a PC, etc. The output of source 10 is an MPEG (and Dolby AC-3) encoded digital signal at baseband frequency. This baseband signal may be applied directly to a baseband input of a digital television receiver 24. However, in accordance with the invention, the baseband signal is applied to an ATSC encoder 12 where the signal is subjected to interleaving, randomizing, R/S error encoding and Trellis encoding. Field and segment syncs are added, and while not indicated, a pilot is inserted and equalization filtering is employed. (See ATSC Standard A/53, ATSC Digital Television Standard for a detailed description of these operations.) The signal is then supplied to a digital to analog (D/A) converter 14. D/A 14 supplies the analog signal to a pair of multipliers 13 and 15 that in turn supply signals to a pair of SAW (surface acoustic wave) filters 16 and 18. Multipliers 13 and 15 are each supplied with a frequency F1 and F2, respectively for producing two different outputs. The SAW filters are selectively controlled by a switch 20, with one of the SAWs being used for one selected channel RF output and the other being used for another selected channel RF output. The particular RF channel selected is dependent upon the environment in which the encoder-modulator is used, in particular the availability and type of RF channels in the receiving area. The SAW filters are relatively low cost devices and are extensively used in television receivers.

Those skilled in the art will recognize that highly accurate modulators generate I and Q signals with the signals being combined to cancel one of the sidebands and

generate a vestigial sideband signal. Such modulators are quite complex and very expensive. In one form of the invention, that arrangement is replaced with a multiplier (13, 15) and a SAW filter (16, 18). The output of the multiplier is a double sideband suppressed carrier signal. The following SAW filter removes most of one sideband (preferably, although not necessarily, the lower sideband) to produce a VSB signal and also approximates the nominal Nyquist slope of the channel bandpass. As a result of the less than nominal bandpass characteristic, the transmitted signal will be characterized by a degree of impairment in the form of intersymbol interference (ISI).

The SAW filters shape the edges of the signal bandpass to approximate the Nyquist slopes, nominally called for at the band edges in the ATSC standard. (The Nyquist slopes may be seen by reference to the solid line curve of FIG 3.) The SAW filter characteristics also provides for adjacent channel rejection. The filtered signal from the selected one of the SAWs is applied to an RF upconverter 22, which upconverts the signal to any desired RF channel, channels 3 or 4 being the ones normally used.

The encoded and modulated VSB signal is supplied over a cable network 23, which may comprise a single coaxial cable or a relatively complex home cable network, to an RF channel input of a tuner 26 of a VSB digital television receiver 24. The signal may also be amplified by a low power RF amplifier 25 (shown in dotted line in FIG. 1) and transmitted wirelessly to the digital television receiver in an assigned RF broadcast television channel. The received signal is supplied through a companion SAW filter to a VSB demodulator 28 where the baseband digital signal is recovered. The demodulated signal is applied to an equalizer 30 that operates to adjust the response of the receiver to very closely match the solid line Nyquist response (FIG 3) thereby correcting any signal impairments, including any intersymbol interference introduced in the transmitter and any linear distortions introduced in the communications link (i.e. the cable network or wireless link) that collectively are below a given threshold level that is dependent upon the nature of the equalizer. The signal from equalizer 30 is processed by a forward error correction subsystem 31 to correct any residual errors due to intersymbol interference and errors due to noise,

both white and impulse, introduced by the cable network or wireless link. The performance of equalizer 30 and error correction subsystem 31 sets the limit on the amount of intersymbol interference and linear distortion which can be introduced by the transmitter and communications channel before the system suffers serious degradation.

The corrected signal (in MPEG encoded form) is supplied to a transport demultiplexer 32 that has separate outputs for the video and audio portions of the signal. The video portion is applied to an MPEG decoder 34 for decompression and decoding and the audio portion is applied to a Dolby AC-3 decoder 36 for complementary processing. The resultant video and audio signals are applied to a video processor 38 and an audio processor 40, respectively.

It will be appreciated by those skilled in the art that the RF signal is not as distance sensitive as a baseband signal and the coaxial cable environment further minimizes errors or impairments being introduced in transmission. However, even if some signal impairments are introduced, they may be compensated for by the corrective circuitry built into the VSB digital television receiver, in particular the equalization circuitry. The result is a signal translation arrangement that results in excellent transfer of signal from source 10 to VSB digital television receiver 24, since the signal is VSB encoded and any errors or signal impairments below a given threshold are correctable in the television receiver.

In contrast, any baseband digital signals that are supplied to television receiver 24 are introduced after equalizer 30 and error correction subsystem 31 and are consequently not subject to the corrective effects of the circuitry in the VSB digital television receiver. Such signals are also distance limited and subject to uncorrectable errors or impairments, which makes the method of the invention far superior.

In further accordance with the invention, where the digital television receiver has provision for receiving both a digital and an analog NTSC signal, in establishing priority of the RF channel output of upconverter 22, the first choice is to supply the signal on a vacant RF channel in the service area of the television receiver and the second choice is to supply it on the digital one of a pair of digital and analog NTSC

RF channels in the service area of the television receiver. In this way, any NTSC interference into the digital channel can be minimized by the circuitry in the digital channel of the television receiver.

The invention resides in the concept of introducing a given level of impairments in the encoded digital baseband signal and taking advantage of the signal correction circuitry that is built into the front end of the digital television receiver to compensate for such impairments. The cost is kept minimal since in the application of the invention, transmission power is very low, distance is limited, the coaxial cable is a low noise environment and the channel shape (Nyquist slope) need not be as rigorously defined for adjacent channel rejection, signal radiation, etc. This translates into low cost filtering to create a less-than-nominal Nyquist slope. While this will clearly cause some intersymbol interference, as mentioned above, all such signal impairments that are below a predetermined threshold, may be compensated for in the digital receiver by the cooperative action of complementary filtering, the equalization circuitry, and the forward error correction circuitry.

The encoder-modulator of FIG 2 is a different version of the invention. Here the low cost SAW filters of FIG 1 have been replaced by digital filters 50, indicated as being FIR (finite impulse response) filters. A digital modulator 52 is supplied with the output of a first local oscillator 56 and converts the filtered input signal to a first IF signal having a frequency, for example, of about 12 MHz. This signal is applied to D/A 14 and thence to an RF upconverter 54 that is supplied with the output of a second local oscillator 58. Local oscillator 58 is controlled by a switch 60 to develop an RF output from upconverter 54 at either of a pair of RF channel frequencies, as in the tuner of FIG 1. The output signal is transmitted to the television receiver over coaxial cable 23. This version of the invention appears to be a more stable system. Since both systems will involve integrated circuitry, it remains to be seen whether the cost of the SAWs in the FIG 1 version will be less than the cost of the additional chip area required in the integrated circuit implementation of the FIG 2 version.

In FIG 3 the solid line curve indicates the ideal Nyquist slope channel bandpass response characteristic of the transmitted signal. The dashed line curve

indicates the less-than-nominal Nyquist slope that results from using the low cost SAWs 16 and 18 in FIG 1 and the dotted line curve represents the response for the FIG 2 implementation using the FIR filters 50. The curves should be recognized as being representative only and their actual shapes are dependent upon the precision and the number of the filtering elements used. As mentioned, because of the less-than-nominal bandpass characteristic produced by either the SAW or the FIR filter embodiment of the invention, a certain level of intersymbol interference will be introduced into the transmitted signal. However, as discussed above, the amount of any such intersymbol interference, together with any noise introduced into the signal over the communications link, can be substantially corrected in the television receiver to provide near perfect signal translation and reception. In this manner the invention permits a low cost, high performance encoder-remodulator by deliberately selecting lesser tolerance components and applying the signal to a digital receiver that has the capability of compensating for signal impairments below a given threshold.

What has been described is a novel method and apparatus for translating a digital television signal from a digital source to a VSB digital television receiver. It is recognized that numerous changes to the described embodiment of the invention will be apparent to those skilled in the art without departing from its true spirit and scope. The invention is to be limited only as defined in the claims

What Is Claimed Is:

1. A method of operating a digital signal system for supplying a digital television receiver having correction circuitry capable of correcting impairments in a received signal that are below a

predetermined threshold comprising:

developing a compressed baseband digital signal;

encoding the compressed baseband signal in a given format for digital transmission; and

modulating the encoded compressed baseband digital signal on an RF carrier for direct application to the RF input of the digital television receiver;

the modulating step resulting in a less-than-nominal bandpass which produces impairments in the transmitted signal that are less than the predetermined threshold;

whereby the correction circuitry is capable of correcting the impairments introduced in the modulating step.

2. The method of claim 1, wherein the encoding step includes data interleaving, data randomizing, error protection and the addition of VSB field and segment syncs, and further comprising:

performing the modulating step at a low power level.

3. The method of claim 1, further comprising:

supplying the encoded compressed baseband digital signal through a first filter having a response designed to cooperate with a second filter in the digital television receiver for producing a less-than-nominal Nyquist slope.

4. The method of claim 1, further comprising:

supplying the encoded compressed baseband digital signal through a first filter having a response designed to cooperate with the equalization circuitry and a second filter in the digital television receiver for generating a nominal Nyquist slope and providing adjacent channel rejection at each end of the signal bandpass.

5. The method of claim 1, wherein the television receiver comprises a digital signal processing system and an analog NTSC signal processing system and further



comprising generating the modulated RF digital signal for application to the digital processing system of the television receiver.

6. The method of claim 1, wherein the RF carrier is applied to the RF input of the digital television receiver by a coaxial cable network.

7. The method of claim 1, wherein said modulating step comprises:
multiplying the baseband signal by a predetermined carrier frequency to generate a double sideband suppressed carrier signal; and
using a filter to remove one of the sidebands to develop a VSB signal and provide the less-than-nominal bandpass.

8. The method of claim 7, wherein the filter is a SAW and wherein the bandpass has a less-than-nominal Nyquist slope.

9. The method of claim 1, wherein the correction circuitry comprises equalization and forward error correction circuitry.

10. The method of claim 1, wherein the RF carrier is applied wirelessly to the RF input of the digital television receiver over a broadcast television channel.

11. A system for supplying a compressed digital baseband signal to a digital television receiver that includes correction circuitry capable of correcting impairments in a received signal that are below a predetermined threshold, comprising:

a source of compressed baseband signal;
an encoder for encoding said baseband signal in a given digital format;
a modulator for modulating said encoded baseband signal on an RF carrier;
said modulator having a less-than-nominal bandpass that produces impairments in the translated signal that are below said predetermined threshold; and
means for directly applying said modulated signal to an RF input of said digital television receiver, whereby said correction circuitry is capable of correcting said impairments introduced by said modulator.

12. The system of claim 11, wherein said encoder and said digital television receiver each include a filter, and wherein said filters cooperate to generate a less-than-nominal Nyquist slope.



13. The system of claim 12, wherein said filters and said equalization circuitry cooperate to generate a nominal Nyquist slope and provide adjacent channel rejection at each end of the signal bandpass.

14. The system of claim 11, wherein said given digital format is VSB, said compressed digital signal is in MPEG form, said encoder includes a data randomizer, a data interleaver, error protection circuitry and means for adding VSB frame and field syncs and wherein said modulator operates at low power.

15. The system of claim 11, wherein said RF carrier is applied to the RF input of the digital television receiver by a coaxial cable network.

16. The system of claim 11, wherein said digital television receiver comprises a digital signal processing system and an analog NTSC signal processing system and wherein said modulated RF digital signal is generated for application to the digital processing system of the television receiver.

17. The system of claim 11, further comprising:

 multiplying means in said modulator for developing a double sideband suppressed carrier signal from said baseband signal; and

 filter means coupled to said multiplying means for substantially removing one of said sidebands to develop a VSB signal and for producing said less-than-nominal bandpass.

18. The system of claim 17, wherein said filter means comprises a SAW filter and wherein said bandpass includes a less-than-nominal Nyquist slope.

19. The system of claim 11, wherein the correction circuitry comprises equalization and forward error correction circuitry.

20. The system of claim 11, wherein the RF carrier is applied wirelessly to the RF input of the digital television receiver over a broadcast television channel.

