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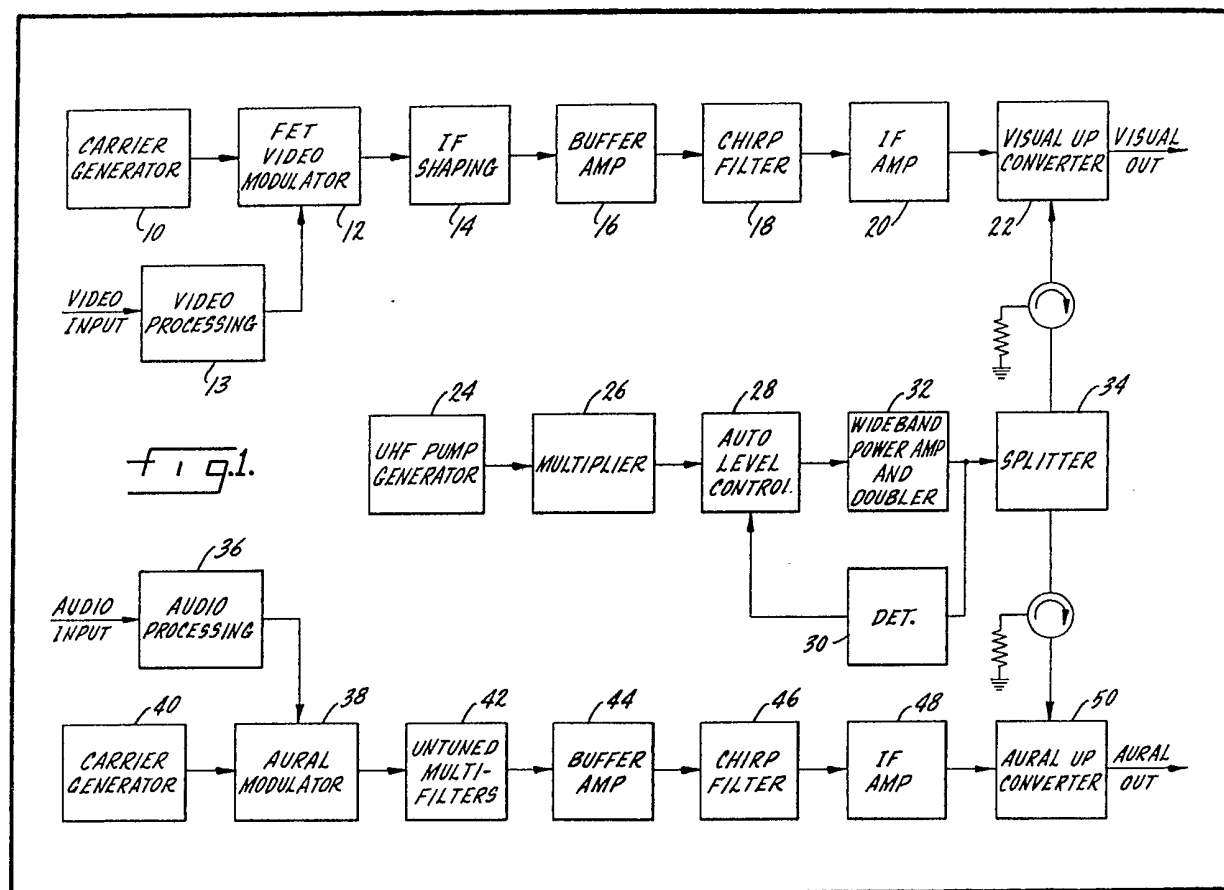
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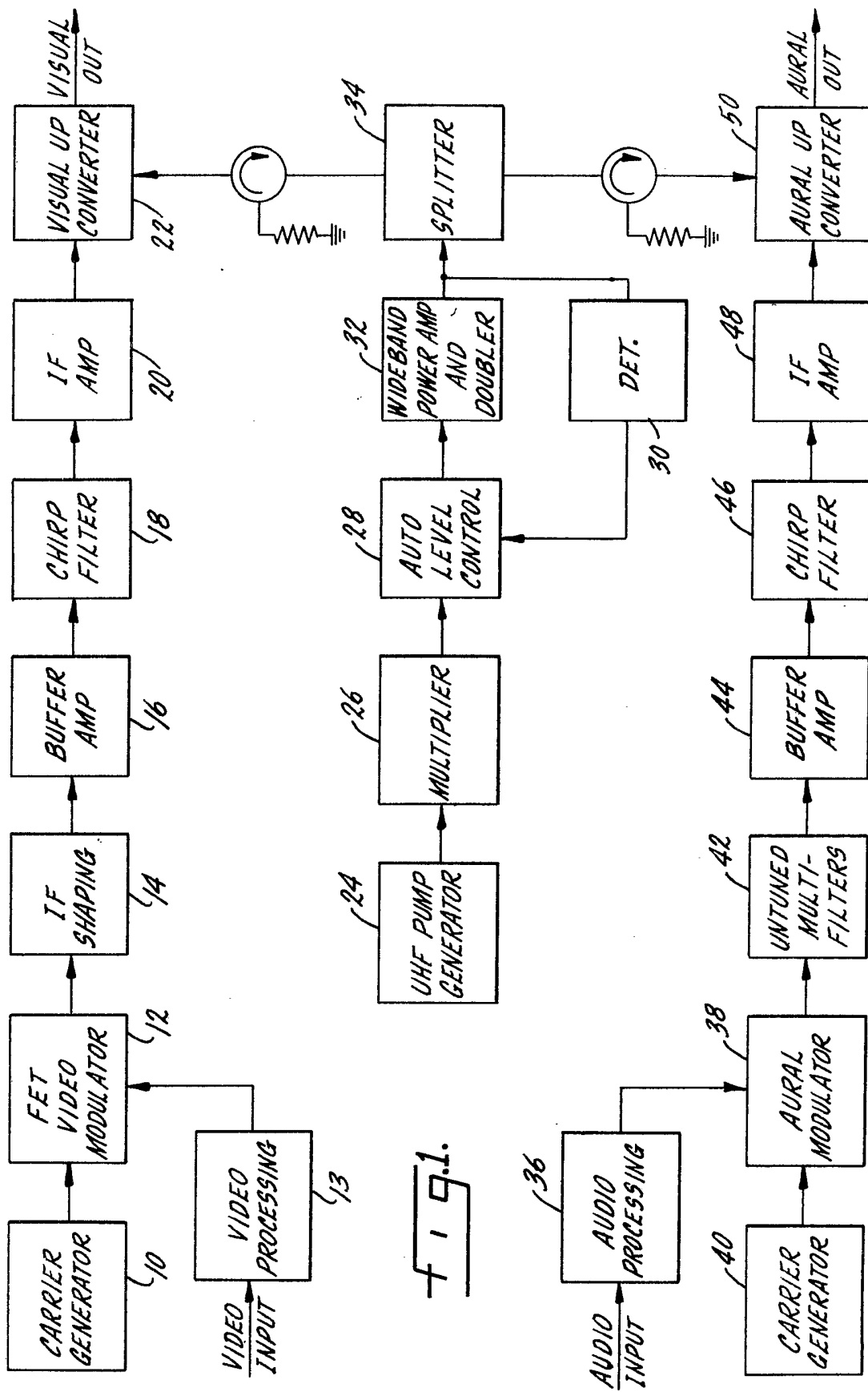
(54) Video scrambling and descrambling means using frequency dependent delay means

(57) A television video signal is scrambled by the application of a frequency dependent variable delay. The delay is applied by a frequency dependent device, e.g., a chirp filter (18). The application of the delay to the video signal, can be achieved either by a bandpass chirp filter or by low pass chirp filters 84 (Fig. 4, not

shown) which are applied to both in-phase and quadrature components of the video signal. The audio signal, conventionally accompanying the video signal may have similar delay characteristics applied to it. The delay may be applied by a non-varying chirp filter; by a plurality of parallel connected chirp filters which are switched in and out of the scrambling circuit in accordance with predetermined controls; or the delay may be applied by a chirp filter which itself has one or more characteristics varied or variable in accordance with a controlled pattern. The signal is unscrambled (Fig. 5, not shown) at the receiver station by applying the inverse of the delay which was applied at the transmitting station.



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FIG. 2.

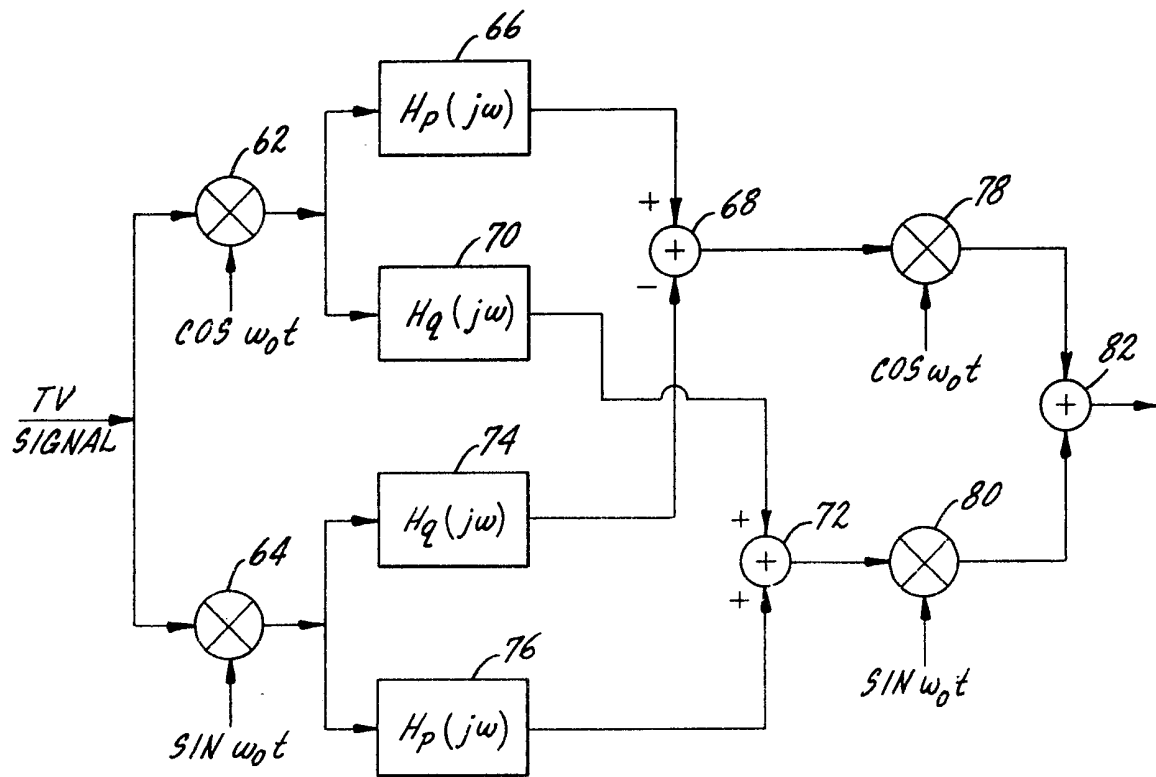
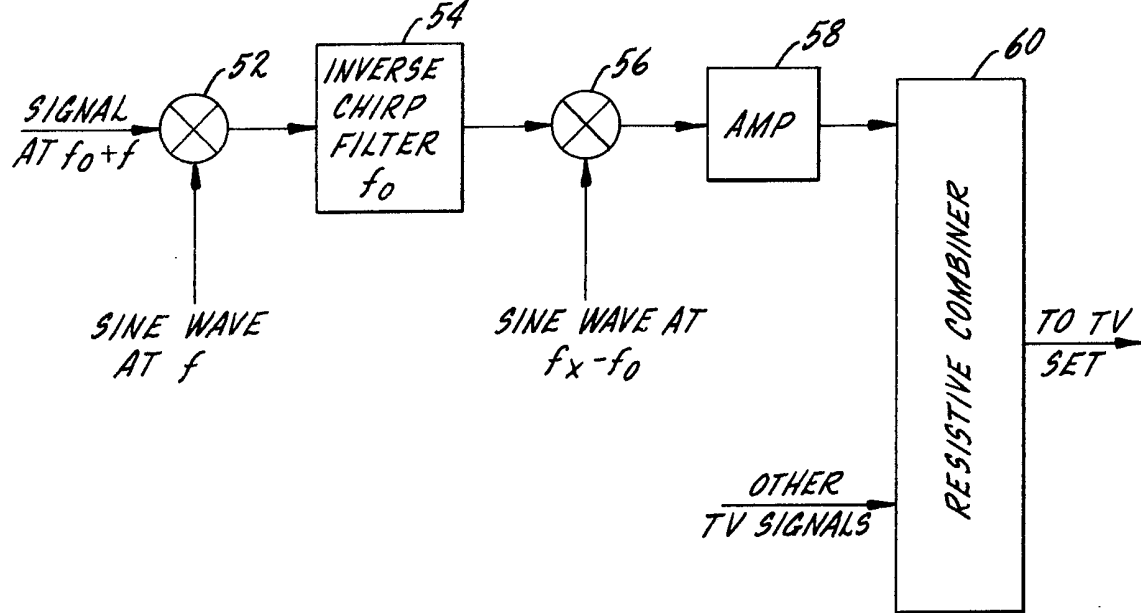
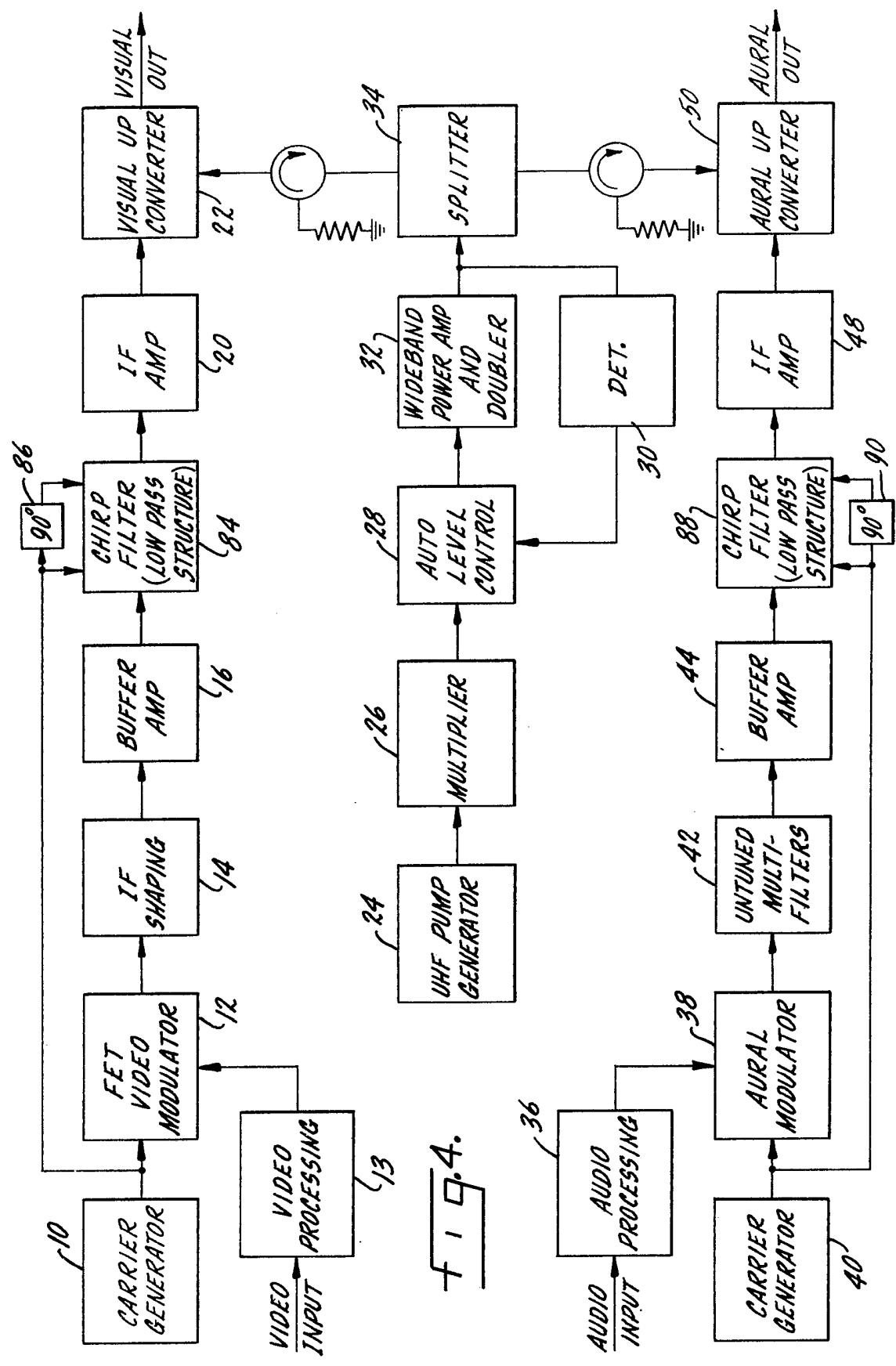


FIG. 3.



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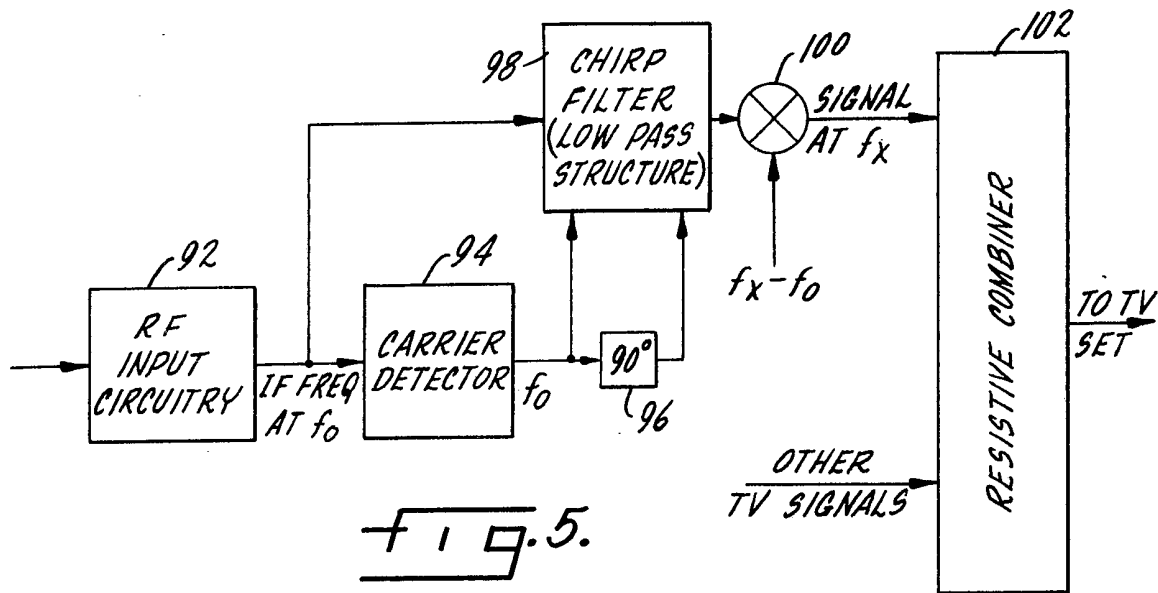


Fig. 5.

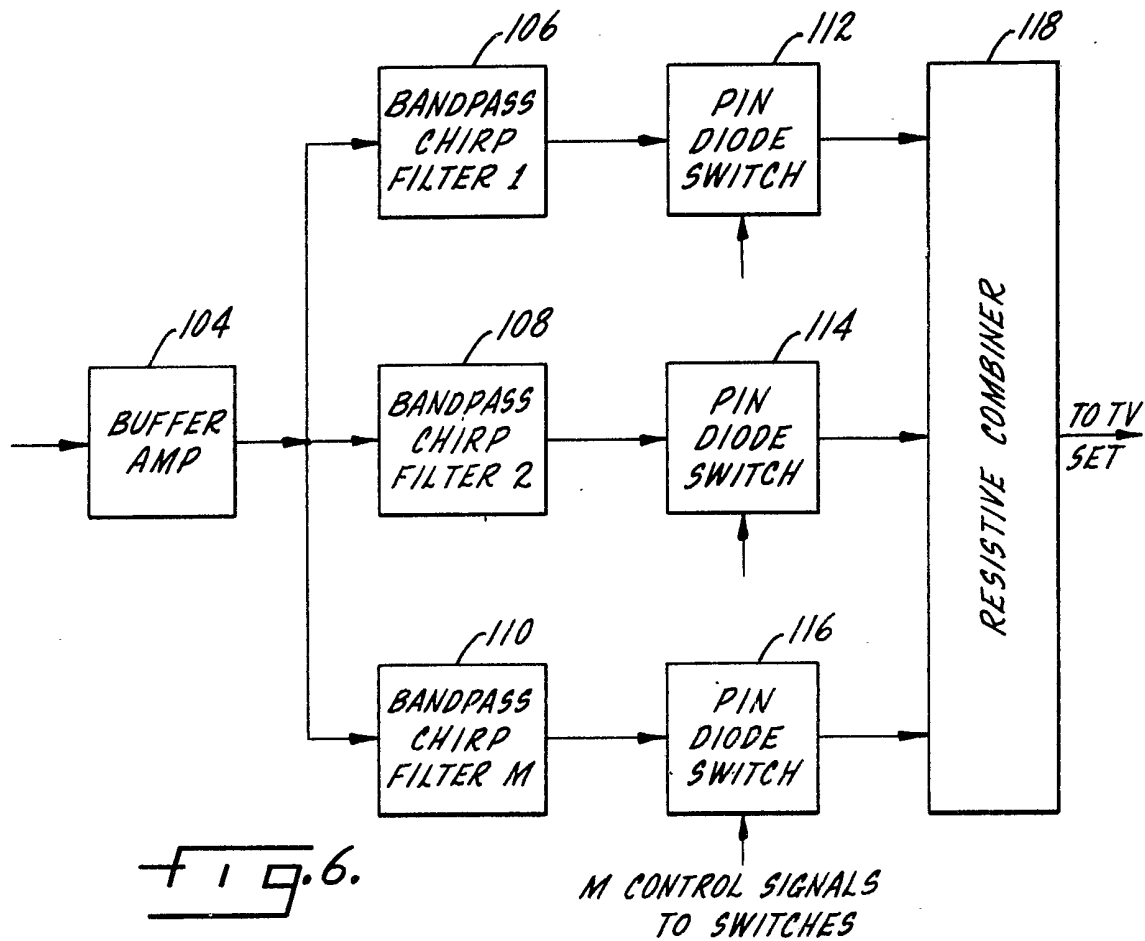


Fig. 6.

SPECIFICATION

Video scrambling and descrambling means using frequency dependent delay means

Summary of the invention

5 The present invention relates to the scrambling and descrambling of television video signals and is particularly concerned with the application of frequency dependent delay to the video signal and essentially the inverse of such delay applied to the video signal at a receiver location. 5

A primary purpose of the invention is a video scrambling transmitter and receiver of the type described in which the delay characteristics are applied by a chirp filter.

10 Another purpose is a video scrambling system in which the chirp filter functions as a bandpass device. 10

Another purpose is a video scrambling system in which the chirp filter functions as a low pass device.

Another purpose is a video scrambling system in which the characteristics of the delay means are variable, either by the delay device itself or by using a plurality of such devices.

15 Another purpose is a video scrambling system in which delay is applied to the video signal by charge coupled devices. 15

Other purposes will appear in the ensuing specification, drawings and claims.

Brief description of the drawings

The invention is illustrated diagrammatically in the following drawings wherein:

20 Figure 1 is a block diagram of a television exciter modulator including the scrambling filter delay means disclosed herein, 20

Figure 2 is a block diagram of a descrambling device usable with the transmitter of Figure 1,

Figure 3 is a diagram illustrating a variant form of chirp filter implementation,

25 Figure 4 is a block diagram, similar to Figure 1, showing the chirp filter scrambling implementation of Figure 3 applied to a television transmitter, 25

Figure 5 is a block diagram of a descrambling device usable with the scrambling device of Figure 4, and

Figure 6 is a block diagram showing a variant form of the invention.

Description of the preferred embodiment

30 Over the past two decades, with the substantial advances made in television equipment and the different types of available programming, a substantial market for pay TV or subscription television has developed. Over this same period of time an almost unlimited number of schemes for scrambling and descrambling video signals have similarly been developed. The more complicated, and thus more secure, scrambling systems have the disadvantage of high cost, whereas, the simpler approaches have 35 the disadvantage of being susceptible to signal piracy. The present invention provides a scrambling system which is both inexpensive and secure. 35

40 A chirp filter whose delay characteristics are frequency dependent is used as the scrambling and descrambling principal component. The characteristics of the chirp filter may be fixed; there may be a plurality of such chirp filters connected in parallel and switching means to connect different filters at different times, or the characteristics of the chirp filter may itself be variable on a timed basis and in a controlled manner. 40

Considering first the application of a single chirp filter with non-varying characteristics, the frequency function of the chirp filter is given by the equation:

$$H_s(j\omega) = \exp[-x(\omega - \omega_0)^2 + jy(\omega - \omega_0)^2] + \exp[-x(\omega + \omega_0)^2 - jy(\omega + \omega_0)^2] \quad (1)$$

45 where x and y are parameters of the desired scrambling mode and ω_0 the nominal carrier frequency of the modulated wave form in radians per second. Descrambling is achieved by essentially the inverse filter applied at the receiver of an individual subscriber with the frequency function for the filter at the receiver being given as: 45

$$H_d(j\omega) = \exp[-x(\omega - \omega_0)^2 - jy(\omega - \omega_0)^2] + \exp[-x(\omega + \omega_0)^2 + jy(\omega + \omega_0)^2] \quad (2)$$

50 When H_d and H_s are cascaded, as they would be when applied in a scrambling and descrambling environment to the video signal, the resultant mathematical expression of the waveform is as follows: 50

$$H_d(j\omega)H_s(j\omega) = \exp[-2x(\omega - \omega_0)^2] + \exp[-2x(\omega + \omega_0)^2] + 2\exp[-x(\omega - \omega_0)^2]\exp[-x(\omega + \omega_0)^2]\{\exp[2jy(\omega + \omega_0)^2] + \exp[-2jy(\omega - \omega_0)^2]\} \quad (3)$$

55 The last term in equation (3) is essentially zero when x and ω_0 are chosen to make H_d and H_s bandpass filters. Thus, the bandwidth of H_d and H_s is of the order of 55

$$\frac{1}{\sqrt{2x}}$$

indicating that if x is small enough relative to the reciprocal of the modulated video bandwidth, the cascade of the scrambling and descrambling filters leaves the ultimate video signal unaltered. Since conventionally a video signal requires a 4 MHz bandwidth, as will appear in more detail hereinafter, x will be of the magnitude of 7.9×10^{-16} .

Figure 1 shows a specific implementation of the chirp filter concept disclosed above. A carrier generator 10 will provide the conventional modulating carrier waveform and provides one input for a field effect transistor video modulator 12. The input video signal is applied to a video processor 13 which provides the other input to modulator 12. The output of modulator 12 is connected to an IF shaping circuit 14 whose output is connected to a buffer amplifier 16. The output from amplifier 16 is the input to a chirp filter 18 having the characteristics described above in equation 1. Such filters are well known in the art and do not have specific component designations, but, rather, are manufactured to the requirements of a particular customer. In this particular implementation surface acoustic wave devices (SAW) provide the most efficient type of chirp filter. The output from chirp filter 18 is connected to an IF amplifier 20 whose output in turn is connected to a visual up converter 22.

A UHF generator 24 is connected to a multiplier 26 whose output is connected to an automatic level control circuit 28 which works in conjunction with a detector 30 and a wide band power amplifier and doubler 32. The output from doubler 32 is connected to a splitter 34 whose output in turn is connected to the visual up converter 22. This circuit is particularly arranged for a UHF subscription television channel. Thus, the output from converter 22 is the video signal, modified by the delay characteristics of the chirp filter and raised to the frequency of a specific UHF channel.

As in most subscription television systems, the audio may also be scrambled. It is not necessary that the audio always be scrambled, but disclosed herein is an audio processor unit.

The audio input is connected to an audio processor 36 which provides one input for an aural modulator 38, the other input being provided by a carrier generator 40. The output from modulator 38 is connected to a series of untuned filters indicated at 42 with the output from the last filter being connected to a buffer amplifier 44. A chirp filter 46 of the same characteristic as chirp filter 18 is connected to the output of amplifier 44 and has its output in turn connected to an IF amplifier 48. Amplifier 48 is connected to an aural up converter 50 which receives the other output from splitter 34 to raise the output signal to that of a conventional UHF channel. Thus, the output from the transmitter is the video and audio signals raised to an appropriate UHF level if that is to be the transmitting medium and with both the audio and video signals delayed in a manner which is frequency dependent by the application of the audio and video modulated carrier waveforms to the described chirp filters having the characteristics of equation 1.

To descramble the "chirped" video, a subscriber's receiver must include the circuitry illustrated in Figure 2. A mixer 52 has one input of the video signal and a second input of a sine wave at a selected frequency to provide a mixer output of an IF frequency f_0 . A buffer amplifier may also be inserted at this point if necessary. The scrambled video signal at frequency f_0 is applied to inverse chirp filter 54 having the characteristics described in equation 2. Thus, the output from chirp filter 54 will be a video signal in which all of the delay applied at the transmitter has been removed. The unaltered video signal is then ready for processing for use in the subscriber's receiver. The output from chirp filter 54 is applied to a second mixer 56 which receives a sine wave at a frequency of $f_x - f_0$ with f_x being chosen such that the output frequency is usable at a subscriber's receiver, normally on a channel not locally broadcast. The output from mixer 56 is applied to an amplifier 58 and then to a resistive combining network 60 which is conventional and is used to provide all of the locally broadcast channels at the television receiver input.

The determination of x and y in the above-described equation is dependent upon the degree to which it is necessary to distort or render the video signal unusable by a conventional receiver. The impulsive response of a scrambling chirp filter of the type described is given by the inverse Fourier Transform of $H_s(j\omega)$ which can be shown to be essentially:

$$h(t) = \exp\left[-\frac{xt^2}{4(x^2+y^2)}\right] \cos\left(\omega_0 t + \frac{yt^2}{4(x^2+y^2)} - \phi\right) \quad (4)$$

It should be noted that:

$$\tan 2\phi = \frac{x}{y} \quad (5)$$

Since the cascade of the scrambling and descrambling chirp filters must pass the 4 MHz video signal in an unaltered form, it follows from equation (3) that for a 2 dB loss in signal at the edge of the 4 MHz passband:

$$2x(4 \times 10^6 \times 2\pi)^2 = 1 \quad (6)$$

5 or

$$x = 7.9 \times 10^{-16} \quad (7)$$

5

At such time as the scrambling chirp filter is hit with a step change, which may for example be a sudden change from a very dark to a very white picture, the delay characteristics of the chirp filter will cause what would normally be a sudden change to be essentially a smear of tones varying from very dark through the grays to white. In essence, the sharpness of the unaltered video is smeared in the distorted video. To enhance scrambling, when the chirp filter receives an impulse of this type, it is desirable to have it ring for approximately 60 microseconds or the duration of one line. This has the advantage of providing striations in the smeared area where there is a change in the color hues. Thus, for the impulsive response to be down to 1/e at 60 microseconds:

$$\frac{x}{4(x^2 + y^2)} (60 \times 10^{-6})^2 = 1 \quad (8)$$

15 or

$$y = 8.4 \times 10^{-13} \quad (9)$$

15

It should be noted that the parameter y is substantially greater than the parameter x as disclosed above in equation (7). It is in this way that the parameters of the chirp filters are chosen and they can be varied with desired characteristics of the distorted video signal.

As a practical matter a more realistic design for the chirp filter may be one in which the response to an impulse would be a ringing of approximately 30 microseconds duration.

The chirp filter described in connection with Figures 1 and 2 is of a bandpass configuration. It is also possible to design a chirp filter utilizing a low pass realization. Specifically, such a realization is based upon separating the video signal into in-phase and quadrature components, separately filtering such components and then reconstituting the video signal with an applied modulating carrier waveform. Looking at Figure 3, the input baseband video signal is applied to a mixer 62 which receives a modulating carrier waveform of $\cos \omega_0 t$. A second mixer 64 applies a modulating carrier waveform of $\sin \omega_0 t$. Each of the resulting products from the mixers are applied to in-phase and quadrature chirp filters having the characteristics as follows:

$$H_p(j\omega) = e^{-x\omega^2} \cos y\omega^2 \quad (10)$$

$$H_q(j\omega) = e^{-x\omega^2} \sin y\omega^2 \quad (11)$$

The in-phase chirp filter connected to mixer 62 is designated at 66 and its output is applied to one input of an additive circuit 68. The quadrature chirp filter 70 connected to mixer 62 has its output connected to additive circuit 72. In like manner, quadrature filter 74 connected to the output of mixer 64 has its output connected to additive circuit 68, whereas, in-phase chirp filter 76 connected to mixer 64 has its output connected to additive circuit 72. The in-phase and quadrature components of the low pass filter implementation illustrated in Figure 3 are connected respectively to mixers 78 and 80 which again have the carrier modulating waveforms of $\cos \omega_0 t$ and $\sin \omega_0 t$ applied thereto. The outputs from the two mixers are additively combined in an adder 82 in which the resultant output will be the video signal having the characteristics of equations (10) and (11) and having the modulating carrier waveform $\omega_0 t$ applied thereto.

Figure 4 illustrates the implementation of the low pass filter structure of Figure 3 in a transmitter. As most of the components of Figure 4 are identical with those of Figure 1, like numbers have been applied thereto. The chirp filter structure is illustrated at 84 and receives its input from buffer amplifier 16. A phase shift device 86 receives an input of the carrier waveform from carrier generator 10. Phase shift device 86 will provide a quadrature carrier waveform to the low pass chirp filter for use as described in Figure 3. The in-phase carrier waveform will be supplied directly from generator 10. In like manner, a low pass chirp filter 88 and a phase shift device 90 are applied on the audio side of the transmitting circuit. In all other respects the transmitter of Figure 4 operates in the manner of the transmitter of Figure 1.

Figure 5 illustrates the descrambling device to be used in conjunction with the low pass chirp filter transmitter configuration of Figure 4. RF input circuitry is illustrated at 92 and will provide an output of the altered video waveform at a frequency f_0 . A carrier detector 94 is connected to a phase shift device 96 to provide in-phase and quadrature carrier signals to a low pass chirp filter structure 98 which will be essentially the inverse as that illustrated in Figure 3 and used in the transmitter

arrangement of Figure 4. The other input for chirp filter 98 will be from RF input circuitry 92 and will be the altered video waveform. The output from chirp filter 98 will be applied to a mixer 100 which again will have an input of a sine wave at a frequency $f_x - f_0$ to provide a video signal output at frequency f_x which customarily will be a locally unused channel. This signal is applied to a resistive combiner 102, similar to Figure 2, to provide a composite of television signals to the subscriber's receiver.

Whereas the chirp filters of Figures 1 and 2 may be SAW-type devices, the low pass filter structure of Figure 3 is best implemented through the use of charge coupled devices.

The above-described implementations of a chirp filter technique have utilized a single chirp filter to apply frequency varying delays to the video signal. Figure 6 illustrates a configuration in which a plurality or series of chirp filters are used with a preset control pattern determining which chirp filter is in circuit at any particular instant. A buffer amplifier 104, which may for example be the same as buffer amplifier 16 in Figures 1 and 4, is connected to three bandpass chirp filters illustrated at 106, 108 and 110 which represent the 1st, 2nd and mth filters in the series. The output of the filters are each connected to pin diode switches 112, 114 and 116, respectively. Each of the diode switches will receive control signals along the inputs indicated by the arrows, which control signals determine which filter is implemented at any one time. The outputs of the diode switches are connected to a resistive combiner 118.

Since the control pattern for the configuration of Figure 6 will require a similar pattern at the receiver, there is a required data path between the transmitter and receiver so that the variations in chirp filter implementation may be followed by the receiver. Such data paths are well known in the art and may be a normally unused portion of a video signal, a video subcarrier, an audio subcarrier or some other available transmission path.

Referring specifically to the low pass filter configuration of Figure 3, it was indicated above that this configuration may be most conveniently implemented by charge coupled devices. Preferably the signal will be sampled, for example at three or four times the chroma frequency, with the samples being supplied to two charge coupled device filters which are sample equivalents of tapped delay lines. For the two filters the tap weights are respectively samples of the function H_p or H_q whose parameters are given by the following equations:

$$\frac{x}{4(x^2 + y^2)} (60 \times 10^{-6})^2 = 1 \quad (12)$$

$$y = 8.4 \times 10^{-13} \quad (13)$$

The analog samples may then be passed through a holding circuit and filtered to the video bandwidth. Each will be remodulated onto carriers that are 90 degrees apart as specifically illustrated in Figure 3.

It is also possible to implement the in-phase and quadrature scrambling concept in a digital manner. The samples may be clocked as before, for example at three or four times the chroma frequency, but then quantized to 12 bits, a number chosen to insure an adequate ratio of signal to quantizing noise power. The chirp filter is then implemented using standard digital methods in a programmable digital device.

Whereas the preferred form of the invention has been shown and described herein, it should be realized that there may be many modifications, substitutions and alterations thereto.

Claims

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Means for scrambling a TV video signal including delay means having a characteristic that is frequency dependent, and means for applying a video signal to said delay means.
2. The scrambling means of claim 1 further characterized in that the delay means has a frequency characteristic responding to the formula:

$$H_s(j\omega) = \exp[-x(\omega - \omega_0)^2 + jy(\omega - \omega_0)^2] + \exp[-x(\omega + \omega_0)^2 - jy(\omega + \omega_0)^2]$$

where x and y are parameters of the delay means and ω_0 is the nominal carrier frequency of the modulated waveform in radians per second.

3. Means for scrambling a TV video signal including means for filtering the video signal with filter means having a delay characteristic which is frequency dependent.
4. The scrambling means of claim 3 further characterized in that said filter has a delay characteristic responding to the formula:

$$H_s(j\omega) = \exp[-x(\omega - \omega_0)^2 + jy(\omega - \omega_0)^2] + \exp[-x(\omega + \omega_0)^2 - jy(\omega + \omega_0)^2]$$

where x and y are parameters of the filter means and ω_0 is the nominal carrier frequency of the modulated waveform in radians per second.

5. The scrambling means of claim 3 further characterized in that said filter means is a surface acoustic wave device.

5 6. The scrambling means of claim 3 further characterized in that said filter means includes in-phase and quadrature filters responding to the formulas: 5

$$H_p(j\omega) = e^{-x\omega^2} \cos y\omega^2$$

$$H_q(j\omega) = e^{-x\omega^2} \sin y\omega^2$$

wherein x and y are parameters of the filter means.

10 7. The scrambling means of claim 6 further characterized in that the modulating carrier waveform 10 is applied to the video signal both as a cosine function and as a sine function, with said in-phase and quadrature filter means being applied to each of the products of the video signal and the cosine and sine carrier functions, respectively.

15 8. The scrambling means of claim 3 further characterized by and including a plurality of frequency dependent filter means connected in parallel, and means for selecting one of said filter means at any particular instant. 15

9. Means for descrambling a TV video signal scrambled by the application of frequency dependent delay including frequency dependent delay means having a frequency characteristic essentially the inverse of the scrambling frequency dependent delay.

20 10. The descrambling means of claim 9, wherein said delay means has a frequency characteristic 20 responding to the formula:

$$H_d(j\omega) = \exp[-x(\omega - \omega_0)^2 - jy(\omega - \omega_0)^2] + \exp[-x(\omega + \omega_0)^2 + jy(\omega + \omega_0)^2]$$

where x and y are parameters of the delay means and ω_0 is the nominal carrier frequency of the modulated waveform in radians per second.

25 11. The descrambling means of claim 9 further characterized in that said delay means is in the form of a filter having frequency dependent delay characteristics. 25

12. The descrambling means of claim 11 further characterized in that said filter is a surface acoustic wave device.

30 13. The descrambling means of claim 11 further characterized in that said filter means includes in-phase and quadrature filters responding to the formulas: 30

$$H_p(j\omega) = e^{-x\omega^2} \cos y\omega^2$$

$$H_q(j\omega) = -e^{-x\omega^2} \sin y\omega^2$$

14. Scrambling means for scrambling a TV video signal substantially as hereinbefore described with reference to the accompanying drawings.

35 15. Descrambling means for descrambling a scrambled TV video signal substantially as hereinbefore described with reference to the accompanying drawings. 35