

Super Linear Digital Decoder

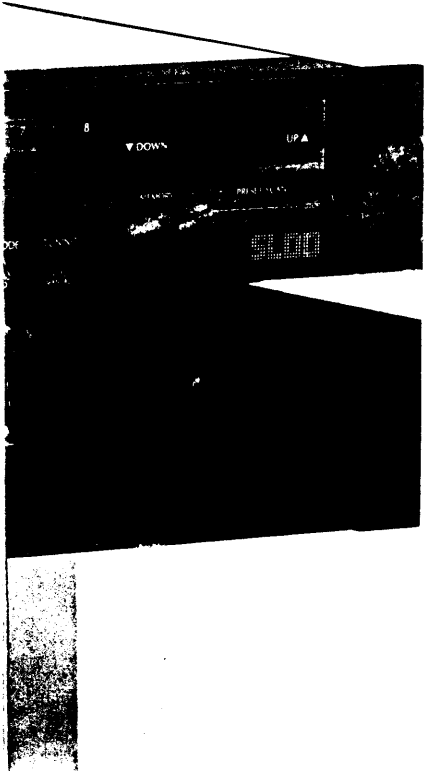
Enjoy the clearest reception you've ever heard; it's as if all interference-causing stations were ban-

Though you may not know it, you may be missing part of your music: as the number of FM stations broadcasting Compact Discs and PCM digital recordings over the air increases, you should be enjoying far better sound from your favorite stations. But probably you're not. The reason: interference from nearby or powerful stations. Is the extra wide dynamic range and low-distortion sound of digital broadcasts all for naught? Not any more, thanks to a new technology from Sansui — the Super Linear Digital Decoder. It lets you enjoy FM sound as clear as if you're listening to the actual Compact Disc. Both noise and distortion due to interference are cleanly rejected, despite that the decoder has made an anti-birdie filter redundant.

Three sources of interference — neighboring station, RF intermodulation and multipath interference

In both urban and suburban areas, a tuner is susceptible to many sources of interference. The most common among them are neighboring station interference, RF intermodulation and multipath.

Neighboring station interference. As the number of stations in an area increases, station frequencies inevitably become closer together: in many areas, stations with frequencies only 100kHz to 200kHz apart from each other are not rare. If a station is sufficiently powerful, neighboring stations may suffer from interference, so much so that even IF filters cannot eliminate the interference. One solution to this type of interference is to use a narrower IF bandwidth in the tuner.



RF intermodulation interference. When two powerful stations are located close to each other on the tuning band, their signals mingle, creating spurious sum and difference signals ("ghosts"). A station suffers from interference if its frequency is the same or nearly the same as one of these spurious frequencies. RF intermodulation interference is the direct result of saturation of a tuner's front end by spurious harmonics created by strong stations.

Multipath interference. This type of interference occurs when signals from a radio station reach a tuner via a number of paths — besides the main path directly from the station, the signal arrives at the tuner after being reflected off nearby buildings, mountains, etc. Multipath results in audible distortion.

Two types of demodulation, one using a square wave, the other a sine wave

The demodulator of a tuner separates the composite signal into separate left and right channel components.

At present two types of demodulation systems are known — one uses a square wave and the other a sine wave for switching the IF signal. The former switches the composite signal with a switching carrier (square wave) created by the demodulator itself. The latter, on the other hand, creates a sine wave, which is multiplied by the composite signal. In either case, the composite signal is multiplied by a demodulating carrier which may be a square wave or a sine wave at a frequency of 38kHz.

Both of these demodulating systems have advantages and disadvantages. The common square-wave demodulator is simple to design. Yet the square wave it uses as a switching carrier contains many harmonics of 38kHz (Fig. 1a). And if the composite signal contains the spurious frequencies created by neighboring station interference and RF intermodulation, the demodulator demodulates these parasites too. The result is a poorer signal-to-noise ratio (Fig. 2).

It's possible to avoid this disastrous result by simply adding what's called an "anti-birdie" filter. This low-pass filter removes the spurious frequencies created by interference before the IF signal is sent to the demodulator, but it does so at a cost: it rolls off the sub-channel signal and causes phase distortion. So the inevitable result is poor separation and other audible evils.

How about the demodulator using a sine wave? Because the demodulating carrier contains no harmonics whatsoever, the demodulator does not demodulate interference-created spurious frequencies, even if the composite signal contains them, hence no anti-birdie filter is required. Therefore, the signal degradation caused by this filter is

avoided completely. This is a positive aspect, but there's a negative aspect too: an expensive analog multiplier is required, and the multiplier affects linearity, signal-to-noise ratio, dynamic range and other hi-fi specifications.

What's the conclusion? The square-wave demodulator offers high linearity, while the sine-wave demodulator does not have the ability to demodulate spurious high frequencies. Is there a way to design a tuner offering only the positive aspects of these two types of demodulators? This dilemma led to the development of the Sansui SLDD — Super Linear Digital Decoder.

SLDD in a nutshell

The Sansui SLDD employs two switching circuits. It switches the composite signal by two square waves formed by the Walsh transform (Walsh waves) and mixed at certain rates. The result is a synthesized output which approximates a sine wave to be multiplied with the composite. Since it is not sensitive to various high frequencies set up by interference, it does not require an anti-birdie filter.

Walsh transform of a sine wave

It's known that by using the Fourier transform, we can resolve any waveform into multiples of sine waves. So even a complex distorted waveform may be expressed as the sum of its fundamental frequency, 2nd-order harmonic, 3rd-order harmonic, and so on. Conversely, you can create any waveform from an aggregate of sine waves.

Likewise, you can resolve any waveform into multiples of square waves (Walsh waves) according to the Walsh transform. Collaterally, a sine wave may be created from multiples of square waves, that is, by superimposing Walsh waves where the amplitude (level) of each wave is adjusted to an appropriate value.

Unlike sine waves, the Walsh waves can be created by a logic circuit, for they are composed of waves which have either of two values (1 or 0) in the binary system. Fig. 3 shows the Walsh waves up to the 7th order.

Fourier transform of a Walsh wave

Then what combination of Walsh waves can create an approximation of a sine wave? Fig. 4 shows the waveform of Walsh wave W1 (a) and that of Walsh wave W7 (b), while (c) is the result of the superimposition of W1 over W7 after the amplitude of each wave is adjusted to an appropriate value (0.65 and -0.27, respectively). As you see, the result of $0.65W1 - 0.27W7$ approximates a sine wave.

With the Walsh waves Fourier-transformed to the 8th order, the 7th order harmonic product of 38kHz, or 266kHz, is

banned from the airwaves

the lowest harmonic component: there exist no lower-order harmonic components.

Actual circuit configuration

Fig. 5 shows a block diagram of the actual demodulator. The bottom half is the Walsh wave generator — a 3-bit counter and a two-EXOR logic circuit — where the 1st-order and 7th-order Walsh waves are generated. Each of these Walsh waves is fed to the input of its double balanced mixer (DBM 1 and 2) where the wave is mixed with the composite signal. The output from DBM 1 is attenuated to a low level, so that the level ratio between the DBM 1 (W1) and DBM 2 (W7) is set at 0.65 and 0.27 respectively. Then the outputs from these two balanced mixer are summed (ADD). The result is equivalent to demodulating the composite signal by the

waveform shown in Fig. 4c, to create a difference signal (L-R). From this point on, operation is routine: the matrix circuit (MTX) matrixes the difference signal and the sum signal (L+R) of the composite signal to separate the left channel information from the right.

In operation, our new demodulator has only a superficial resemblance to a conventional switching demodulator. The fact is, the result of demodulation is equivalent to multiplying the composite by a sine wave containing no harmonics between the 2nd and 6th orders. In other words, our demodulator is not capable of demodulating unwanted frequencies contained in the composite signal. Therefore, no birdie noise can be generated. This means our demodulator needs no anti-birdie filter, the detrimental

filter required by conventional square-wave demodulators which generates noise, degrades channel separation and otherwise harms reproduction quality.

Actual performance

How does our new Super Linear Digital Decoder perform? Fig. 6 compares to what degree it and a conventional demodulator reduce birdie noise. As you see, the SLDD tuner is 40dB or so better at reducing harmonics at 114kHz (3rd order of 38kHz) and 190kHz (5th order). Moreover, harmonics higher than 7th order (266kHz) — spurious interfering signals — do not appear in the composite signal, because they are attenuated by the IF filter.

Fig. 1 Spurious harmonics created by interference

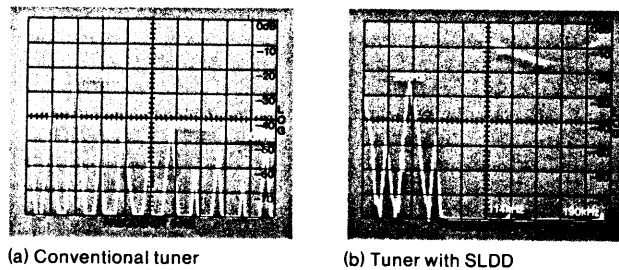


Fig. 3 Walsh waves

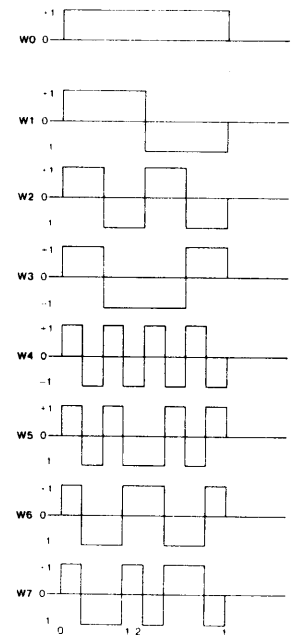


Fig. 2 Spectrum of FM signal and interference

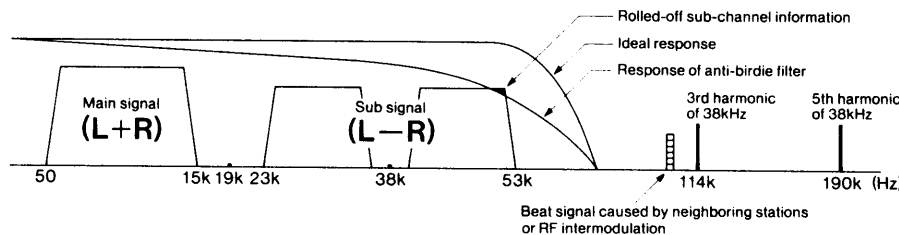


Fig. 4 Fourier transform of Walsh waves W1 and W7

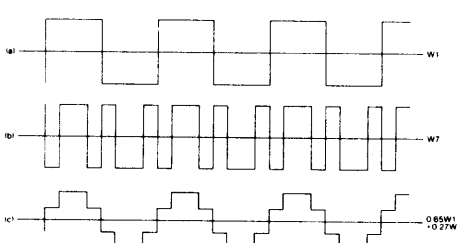


Fig. 5 Walsh wave generator and decoding block

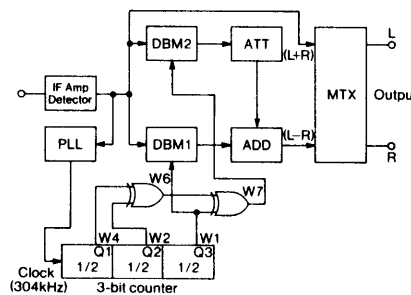


Fig. 6 Comparison of birdie noise cancellation

