AM synchronous demodulator

Used with an existing short-wave AM receiver, this demodulator by Trevor Brook of Surrey Electronics provides SSB, ISB, envelope, DSB and quadrature detection to reduce the effects of poor S:N ratios

Synchronous detection of AM signals has long been known to provide several benefits but, although the technique has been applied to the demodulation of vestigial sideband television for many years, practical systems for radio reception have often proved disappointing. Several of the problems for synchronous radio reception, particularly in the case of short wave, arise from the need to cater for very poor signal-to-noise or interference ratios.

Requirements for regenerated carrier

To avoid the generation of objectionable heterodynes, the phase-lock loop used to produce the synchronous carrier for demodulation must maintain lock down to negative signal-to-noise ratios and not suffer phase modulation in the presence of the following:

- reduced carrier operation, as proposed for future HF broadcasting;
- fading of signal and sidebands;
- selective fading of carrier and sidebands;
- reception of transmissions using either type of dynamic carrier control – increasing or decreasing with audio level;

and

- interfering signals of any description and any strength more than about 30Hz from the wanted carrier.

Conversely, the loop may need to follow phase modulation accurately on the received signal in the presence of various phase-modulated radio data systems on LF and MF broadcasts; spurious hum, synthesizer noise or poor frequency stability on transmissions; and spurious phase modulation by the wanted audio.

Synchronous demodulators are beginning to be included in a number of commercial receiver designs. An example is this general-coverage AM/FM model by Sony (type ICF2001D): its synchronous demodulator can be switched in to give reduced distortion and fading on AM transmissions, and to enable the user to listen to whichever sideband is less subject to whistles and interference.

These latter characteristics are technically equivalent to unfiltered, exalted-carrier, or 'synchronous' reception, where the received signal is limited to provide a carrier which is itself used directly for synchronous demodulation. Finally, if the transmission ceases, the loop should remain very close to its last frequency for an indefinite period and re-acquire lock within a few milli-seconds of the signal re-appearing.

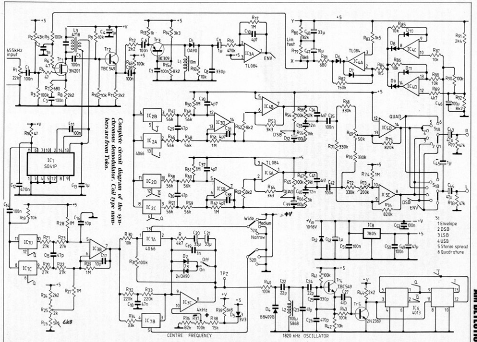
Where there is selective fading, or where single sideband reception is selected, the need for the demodulating carrier to be accurately in phase with the received carrier can be abandoned, since wanted sideband energy exists both in phase and in quadrature with any demodulating carrier. It would be undesirable to attempt to follow the rapid polarity inversion of a carrier which has experienced a selective fade, so the flywheeling action of frequency lock only is required.

Subjective audio level

Apart from the gross distortion which arises in an envelope detector during a selective fade of the carrier, which is overcome by synchronous detection, there is also an objectionable surging in audio level caused by the receiver automatic gain control system unnecessarily increasing the gain. This effect can be ameliorated by an audio gain-control system which senses the peak level of the selected audio output and reduces the gain appropriately.

Circuit and operation

Intermediate frequency of 455kHz enters via the input control, R_1, which allows the gain to be set to suit the level coming from the receiver so that a 100% modulated signal with full carrier does not quite activate the audio limiter. Transistor Tr_1 provides buffering and amplification, an output tuned circuit rejecting harmonics of 455kHz. The SO41P high-performance limiter possesses low AM-to-PM conversion and good limiting action down to very low input levels, its squared output feeding the balanced modulator formed by



Complete circuit diagram of the synchronous demodulator. Coil type numbers are from Toko.

$IC_{7C,D}$ and IC_{3B}. A preset, R_{25}, allows offsets to be cancelled so that the re-generated carrier is accurately in phase.

The op-amp IC_{3C}, with IC_{7A} and IC_{7B}, forms the main loop filter which can be switched between three different bandwidth characteristics. "Wide" allows the loop to lock quickly over a range of ±6kHz and can be used for general tuning around. "Medium" restricts the rapid locking range to ±1kHz, which is about as narrow as one can go when receiving PM data systems carried on certain broadcast stations: France 162kHz, East Germany 177kHz, UK 198kHz, West Germany 1017kHz. Whatever kind of demodulator is used, the presence of such phase modulation on an AM signal does unavoidably lead to some further degradation of reception in the presence of selective fading or co-channel interference. "Narrow" brings the bandwidth down to ±30Hz, which is low enough to avoid disruption by audio components and still allow some margin for drift and microphony of the receiver local oscillator. This position gives a flywheeling effect, so that the regenerated carrier will not attempt to follow the rapid phase changes and polarity inversions of a signal suffering selective fading or cancellation fading, where two stations are nearly on the same frequency.

The "Window" selector switch restricts the voltage swing fed to the varicap, D_4, and thus prevents the loop being captured by signals away from the desired frequency set by the centre frequency control. This facility means that the receiver IF filters can be exploited to the maximum advantage, in addition to the sideband selection on the unit. For instance, the receiver IF filter could be positioned entirely over one sideband of an AM signal, the appropriate sideband selected on the unit and centre frequency offset to where the carrier now lies. The window facility allows the loop to hold lock tenaciously even when the wanted carrier is down the slope of the IF filter or buried beneath noise and interference. In the absence of any steady carrier within 30Hz, the loop will generate a carrier stable enough to permit reception of CW, FSK or suppressed-carrier SSB signals.

The output from the loop amplifier is fed to the varicap, D_4, which controls the frequency of the Colpitts oscillator formed by Tr_4 at 1820kHz. Transistor Tr_5 is a high slew-rate amplifier feeding the divide-by-four circuit, IC_6, which produces in-phase and quadrature feeds of both polarities at 455kHz to drive the balanced modulator and demodulators.

From Tr_1, the 455kHz IF passes through an emitter-follower buffer, Tr_2, and then to the in-phase demodulator, $IC_{2A,B}$ and IC_{3D}, the quadrature demodulator, $IC_{2C,D}$ and IC_{5B} and the low-distortion envelope detector, Tr_3 driving D_1 with constant current. Op-amp IC_{3A} amplifies the output from the envelope detector, while IC_{4B} and IC_{5A} respectively invert and reduce the amplitude of the in-phase and quadrature demodulator outputs and provide drive for the broadband audio phase-shift networks. The outputs from these networks are summed by IC_{5D} for USB and differenced by IC_{5C} for LSB.

Switch S_1 selects the outputs desired. Op-amps $IC_{4C,D}$ form a full-wave peak rectifier which senses the peak audio output level beyond a threshold of +0.5dBμ, giving a small guard band beyond the 0dBμ output for a full-carrier, 100% modulated signal. The output is amplified by IC_{4A}, which drives the storage capacitors through R_{81}, chosen to give an attack time of a few milliseconds. The double time-constant arrangement allows a short burst of audio beyond the threshold to reduce the gain for only a short time, while longer-lasting high levels will cause a slower release time. These characteristics avoid impulsive interference or programme material causing unpleasant pumping effects. The DC output from the time constants is fed to Tr_1, where it controls the 455kHz input-amplifier gain.

The unit requires a positive supply between 10V and 16V at 50mA and IC_8 generates an internal 5V regulated line; a suitable supply can often be obtained from the associated receiver. Audio outputs may be fed into any stereo system, or just the left output used with a mono amplifier or fed back into the receiver's own amplifier and loudspeaker.

Audio outputs

"Envelope" can be convenient for general tuning, to exploit the receiver filters fully when a signal is suffering interference, before going into a synchronous mode. "DSB" gives reduced distortion on heavily modulated and on over-modulated signals arising from selective fading of the carrier. Next come "LSB" and "USB", which provides good results where one sideband of the signal is suffering interference and for the proposed future broadcasts at HF using single-sideband with reduced carrier. "ISB/Stereo spread" gives LSB on the left and USB on the right, which gives interesting effects on fading signals and when the two sidebands are suffering different interference. An unexpected observation has been that propagation effects cause distant lightning static at LF and MF to sound quite different in the two sidebands. Finally, "Quadrature" gives a null on the audio from the strongest station on the channel, thus improving the audibility of any background station. This position can also be used to receive narrow-band frequency modulation, or any other phase modulation.

Lower noise levels occur in the DSB synchronous mode, since noise in quadrature is rejected, while the noise spectrum extends up to half the IF bandwidth. With an envelope detector, noise at one edge of the IF passband demodulates against noise at the other edge, thus producing audio noise extending up to the full IF bandwidth and no rejection of noise in quadrature occurs. The envelope detector and synchronous modes all yield total harmonic distortion below −44dB (0.6%) at 100% modulation at any frequency and the response is 20Hz – 7kHz ±0.5dB. ■

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