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Directionally Selective Doppler System with real-time spectral analyser/recorder.

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Two new developments will be described:

(1) A real-time spectral analyser incorporating a simple recorder which produces an immediate permanent record of the short-term spectral density of rapidly varying signals, and

(2) An ultrasonic Doppler system which is directionally selective and has increased wall-echo rejection and signal/noise ratio. It differs from existing directional (really direction-indicating) systems in that it permits the separate analysis of signals from advancing and receding flow even when both co-exist and are of disparate amplitudes.

While the analyser-recorder unit may well have other applications in the acoustic field, it was primarily developed to form with the Doppler unit an instrument for clinical investigation of blood velocity by the transcutaneous technique. It is designed for use on deep vessels - particularly the aortic arch where the geometry is favourable for quantitative observation[1] but other problems are severe.

Real-time spectral recorder

This consists of a filter bank which is coupled by an array of drive circuits to a specially developed multi-track half-tone recorder. The bank of filters covering the range 5 to 8 KHz is made up of 18 contiguous filter channels, each with a bandwidth of 160 Hz, paralleled at their input.

The output of each filter channel is processed by a driver unit (operating in a switching mode) to give a current having a short-term average value proportional to the logarithm of the "instantaneous" spectral power density in the passband of that channel. The currents from the driver array are passed to an array of electrode strips on the recorder, whence they pass through the thickness of the electrolytic facsimile recording paper to a knife-edge anode. As it moves between the electrodes, the paper is discoloured in proportion to the currents. The resulting pattern of darkening along eighteen parallel tracks represents the short-term spectrum of the input signal in a semi-quantitative manner. (2) Extra tracks carry time and e.c.g. markers, and indicate the axis of zero frequency shift.

The analyser accepts the signal from the direction selective Doppler unit directly, but there is provision for analysing the output of conventional Doppler instruments (or any other signal in the range 0 - 3 KHz) through a frequency-translating 8 KHz modulator.

Directionally Selective Doppler Unit

This differs from conventional continuous-wave Doppler instruments in two main respects: (i) it incorporates an r.f. band-stop filter early in the r.f. amplifier and (ii) a heterodyne system is used in place of the conventional envelope detector.

The band-stop filter following the F. E. T. input stage fulfils several functions: by greatly (>50 dB) attenuating the undesired signal component at transmitter frequency, f_c, it allows the use of a high-gain, r.f. amplifier without overloading. The noise contribution from the following a.f. stages can then be made negligible, and intermodulation at r.f., which can cause the transfer of signals between sidebands, is easier to avoid. The bandstop filter is designed also to give considerable attenuation over a range of frequencies close to f_c (> 30dB at 2MHz $\pm$ 120 Hz), thus making a major contribution to the problem of handling and attenuating the high-amplitude, low-velocity reflections from vessel walls and other interfaces disturbed by heart action.

Demodulation is carried out by mixing with an offset local oscillator frequency ($f_c \pm f_a$) whereby the Doppler sidebands from advancing and receding flow are translated to either side of the new "carrier" frequency, f_a. Either sideband, or parts of both, can thus be brought within the analysing bandwidth of the spectral analyser (5 to 8 KHz) by suitable selection of f_a. In addition to preserving directional information, the heterodyne system gives improved signal-to-noise ratio by avoiding folding-over of the sidebands and f^{-1} noise from audio stages.

A transmitter frequency of 2.0000 MHz was chosen to give deep penetration. Local oscillator frequencies of 2.00833, 2.007, 1.993 and 1.99167 MHz allow the analysis of Doppler shifts in the ranges $\pm$ 280 to $\pm$ 3300 Hz and $\mp$ 1000 to $\pm$ 2000 Hz (excepting the band from -280 to +280 Hz which is suppressed by bandstop r.f. and a.f. filters.)

A separate demodulator/mixer is provided for the loudspeaker output. This can be switched to give either the conventional Doppler sounds (which do not convey directional information) by using the transmitted frequency f_c as the heterodyning input to this mixer, or to generate direction-indicating sounds by using a frequency offset. For ease of listening, the offset in this case is chosen to be $\sim$2KHz.

Application:

The potential of these techniques is still being explored, but some early indications will be given. The equipment will be available for demonstration.

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References:

1. L. H. Light: Nature 224, (1969) p.1119, also J. Physiol. 204, (1969) p.1-2P.

2. L. H. Light: J. Physiol. 207, (1970) 42-42P.