THREE TECHNIQUES OF SPECTRAL ANALYSIS IN ELECTROCARDIOGRAMS

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Electrical signals are functions of time and frequency and can be examined in either domain. Engineers and medical doctors are familiar with data presented in the amplitude time plane. Engineers have found that some data can be more easily interpreted in the amplitude-frequency plane (this is particularly true of pulsed systems). Some efforts have been made to examine medical data in the frequency plane (1), (2). However, it has not been conclusively demonstrated that any distinct advantages can be gained through this method of data presentation.

Currently work is being done[1] at the Toronto Hospital for Sick Children where an IBM 1800 computer is being used to analyze pediatric vectorcardiograms. Many forms of analysis including spectral analysis will be used in an attempt to optimize the diagnostic value of the data presentation. It is too early to tell if frequency analysis will be useful.

There are many ways of transforming into the frequency domain. At the Institute of Bio-Medical Electronics several methods of spectral analysis have been demonstrated using electrocardiograms. First among these is a research program written[2] for the Lab-8 digital computer. It is based on the Cooley-Tukey algorithm and provides a great deal of flexibility through its keyboard interaction. It allows continuous display of an analogue signal and its power spectrum. Cycle time is approximately 1 second for a 512 point analysis. The program allows continuous display of an analogue signal and its power spectrum. This will run automatically or if preferred can be manually controlled. A provision is made for keyboard control of display size, calibration and X-Y plotting of either the input signal or its spectrum. Fig. 1 shows that timing is externally controlled by a voltage controlled oscillator and that the starting position can be advanced or retarded in relation to the synch pulse with one of the front panel potentiometers (the internal clock may be used if so desired). The resulting system has a high degree of flexibility and it is hoped that it will soon be available to other workers through the Decus organization.

A second approach to production of the frequency-amplitude display employs coherent optics. It is a well known optical phenomenon that a spatially modulated coherent light beam when passed through a spherical converging lens will form a two dimensional Fourier transform of the modulation function in the focal plane of the lens. The coherent light source, usually a laser, and the converging lens form an optical analogue processor operating on the spatially dependant function forming a spatial frequency and intensity display at the output. This is a display easily interpreted by an observer (see Fig. 2). Distances measured at the output plane correspond to frequencies at the input plane and the amplitude of each frequency is displayed as the light intensity at that point.

Since the optical processor operates only on spatial signals, it is necessary to transform the time dependent electrocardiogram into a spatially dependant electrocardiogram. Figure 3 illustrates the operation of the converter. The input signal is fed to a modulation amplifier which intensity modulates light source. The scan generator causes the light source to move linearly in one direction thus producing the necessary time to space transformation. This transformation is stored on 35 mm. film using a camera focused on the plane of the traveling light source. At the end of a scan line the light source is returned to the starting position and shifted in a direction orthogonal to the scan line. The result is a raster containing the information on the photographic film which after development is suitable for use in the optical processor. This film provides an inexpensive high density information storage technique; up to six-thousand ECG complexes have been stored on a single 35 millimeter slide. When a slide with the above raster is introduced at the input of the optical processor an average power spectrum of all the ECG complexes stored on the slide is formed at the output. Furthermore, by the use of a positive cylindrical lens, Fourier transforms of each line can be generated separately, so that a simultaneous comparison of spectra from ECG's recorded at different times is possible.

[1] H. O'Beirne, R.S. Fowler

[2] J. Troster

These two methods can be compared to conventional spectrum analyzer techniques. Spectrum analyzers offer some advantages but are based on a repetative signal which of course is not available and must be synthetically repeated. At the low frequency ranges encountered in medical work; stability, bandwidth, response time and frequency dispersion become interrelated problems.

$$\text{optimum resolution} = \sqrt{\frac{\text{dispersion (in Hz)}}{\text{sweep time (in sec.)}}}$$

This shows the trade-offs between sweep time and resolution which severely restrict the application of this type of analyzer to physiological situations.

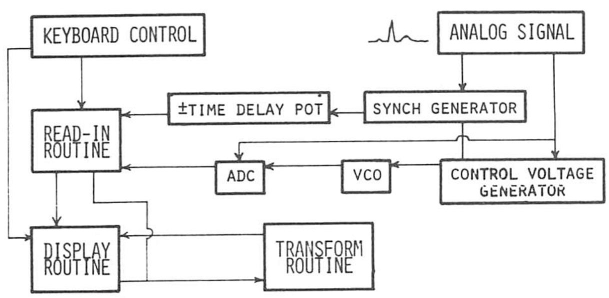

Fig. 1

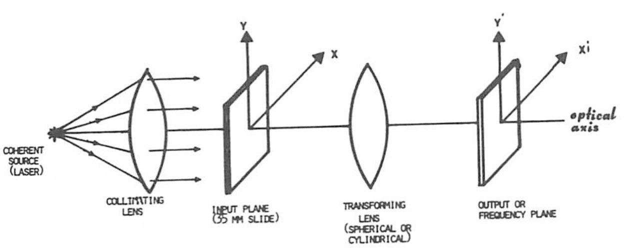

Fig. 2
The optical processor

The three methods of spectral analysis each have advantages and disadvantages. It remains to be seen whether any of them can be used clinically, and perhaps the on going hospital work will determine the medical usefullness of frequency domain display. We have demonstrated that if spectral analysis is applicable, an analogue signal may be transformed to the frequency domain in at least three distinct ways.

REFERENCES

1. P.H. Langner Jr., and D.B. Geselowitz: Characteristics of the Frequency Spectrum in the Normal Electrocardiogram and in Subjects Following Myocardial Infarction, Circulation Res., 8:577 (1960).

2. E.K. Franke, J.R. Braunstein and D. Zellner: Study of High Frequency Components in Electrocardiograms by Power Spectrum Analysis, Circulation Res., 10:870 (1962).

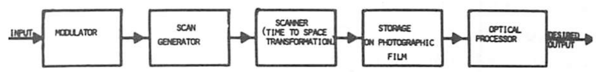

Fig. 3

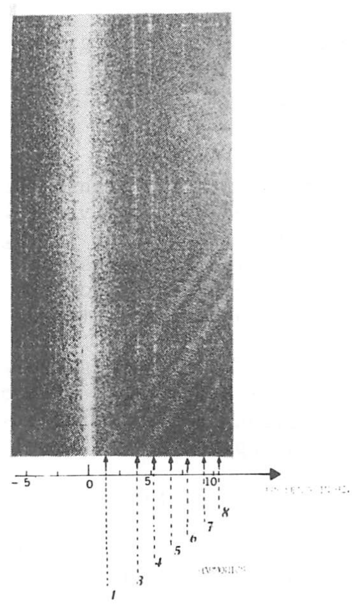

Fig. 4
ECG power spectrum from optical processor