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**United States Patent** [19]  
**Trebino et al.**

[11] **Patent Number:** **5,774,213**  
[45] **Date of Patent:** **Jun. 30, 1998**

[54] **TECHNIQUES FOR MEASURING DIFFERENCE OF AN OPTICAL PROPERTY AT TWO WAVELENGTHS BY MODULATING TWO SOURCES TO HAVE OPPOSITE-PHASE COMPONENTS AT A COMMON FREQUENCY**

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**OTHER PUBLICATIONS**

Kelleher, Joseph F., "Pulse Oximetry," Little, Brown and Co., 1989, pp. 37-62.

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*Attorney, Agent, or Firm*—Townsend and Townsend and Crew LLP

[21] Appl. No.: **518,427**

[57] **ABSTRACT**

[22] Filed: **Aug. 23, 1995**

**Related U.S. Application Data**

A technique for making precise spectrophotometric measurements illuminates a sample with two or more modulated light sources at two or more, typically closely spaced, wavelengths. Light from the sources is combined, homogenized, and directed to the sample, and the light from the sample is collected and detected by a photodetector. The optical output powers of two sources are modulated with the same periodicity and with a reversed amplitude. Variations in the concentrations of species in the sample affect the modulation amplitude representing the sum of the optical powers from two sources in such a way as to produce an output signal. That output signal, based on an electrical component varying with a periodicity at the fundamental frequency, provides a measure of the difference in the transmissions (or other optical properties) of the sample at the two wavelengths. Feedback methods, such as null-point detection, provide stable, sensitive measurements. Wavelength-division multiplexing—required for simultaneous measurements at many wavelengths—is achieved by modulating different pairs of sources at different frequencies.

[63] Continuation-in-part of Ser. No. 426,790, Apr. 21, 1995, abandoned.

[51] **Int. Cl.** <sup>6</sup> ..... **G01N 21/31**

[52] **U.S. Cl.** ..... **356/320; 356/41; 356/408**

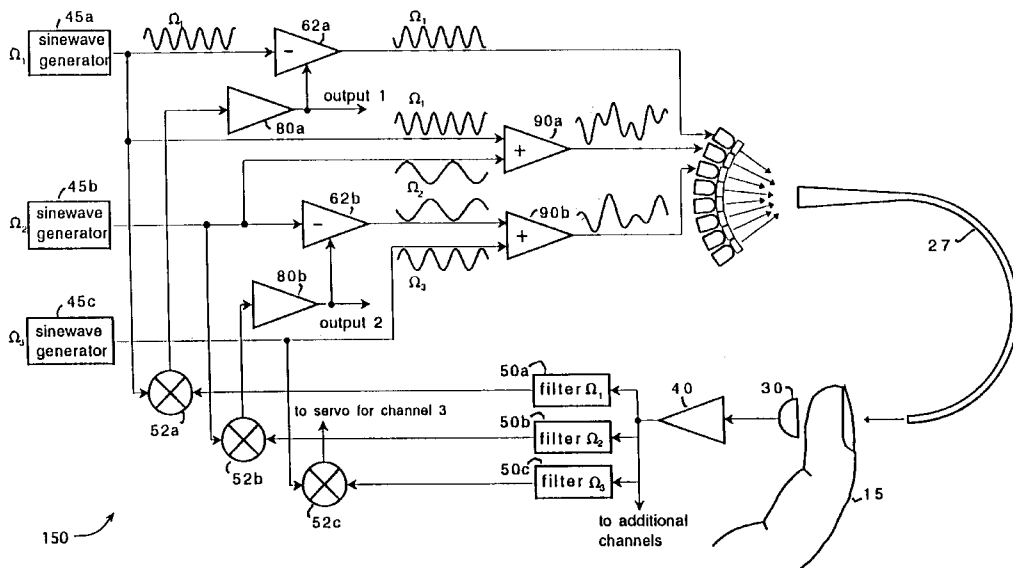
[58] **Field of Search** ..... **356/41, 321, 408, 356/320**

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**11 Claims, 11 Drawing Sheets**



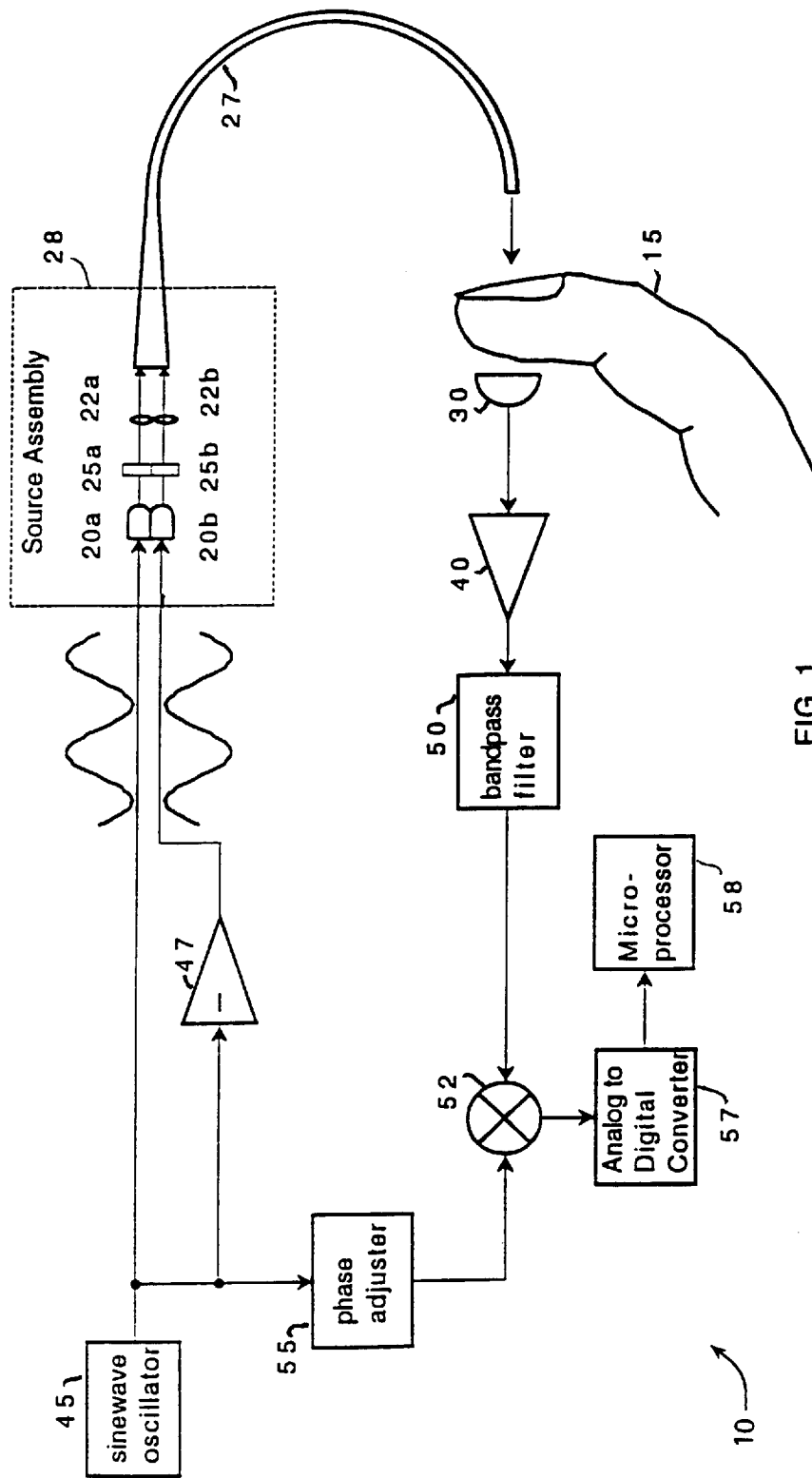


FIG. 1

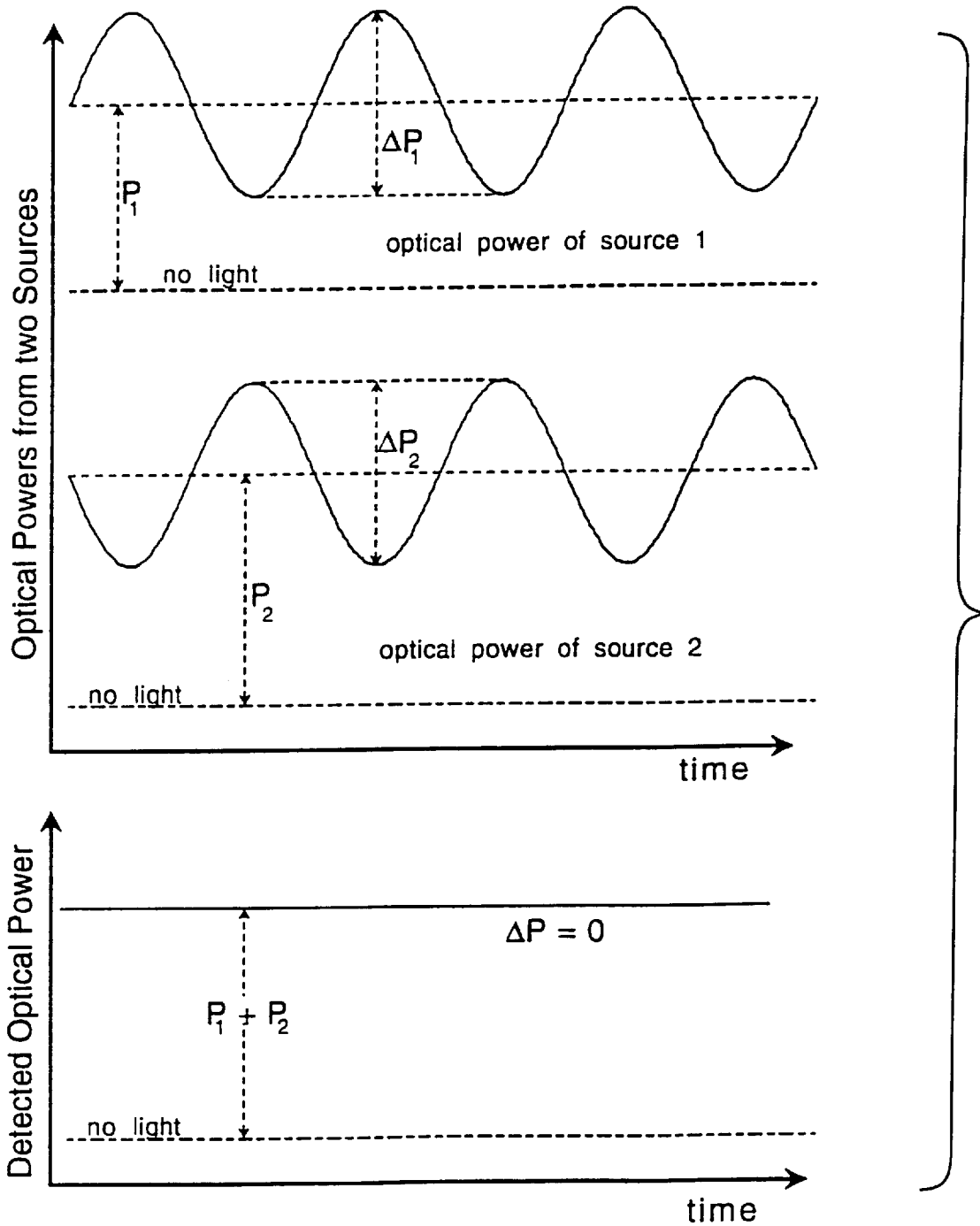


FIG. 2a

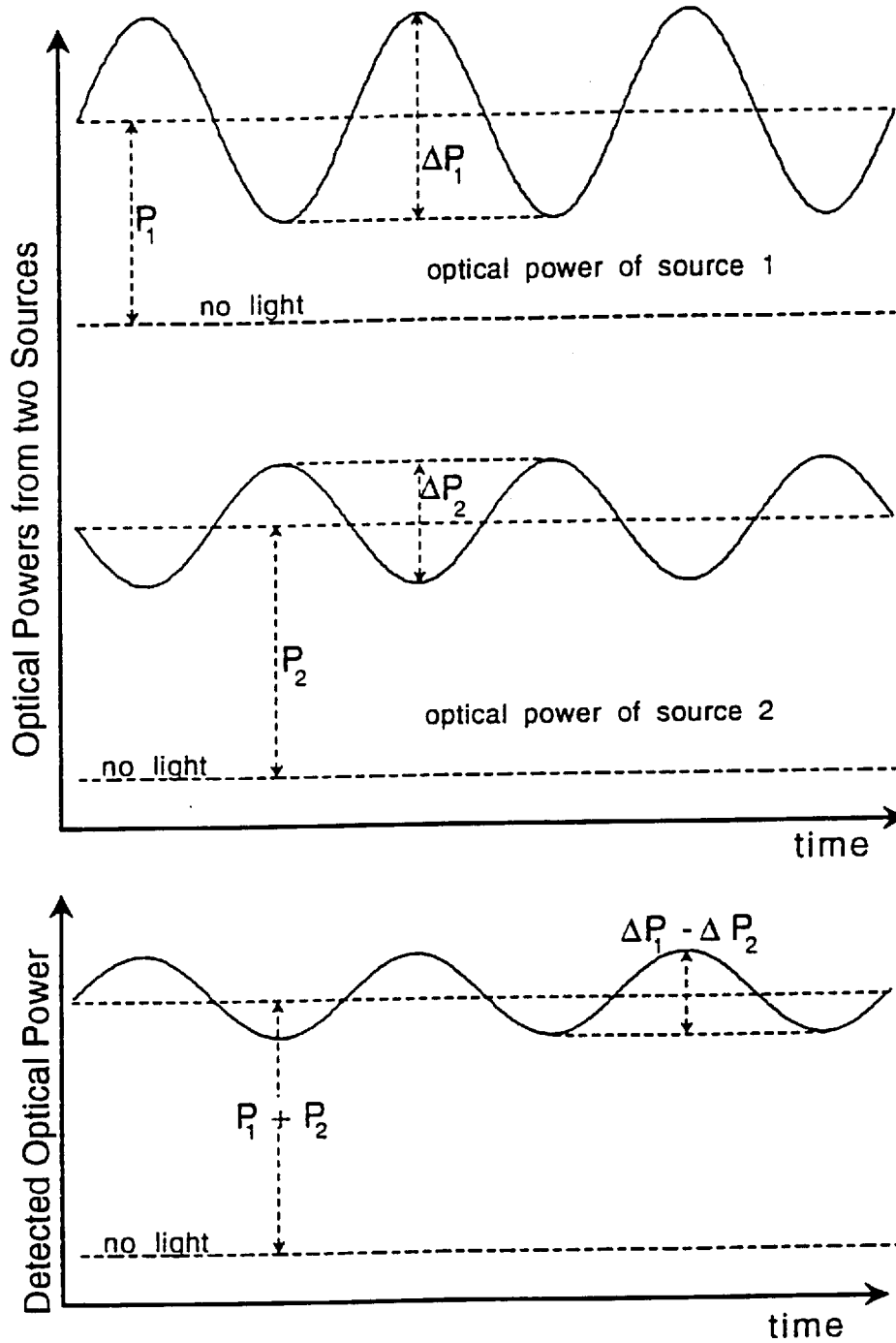


FIG. 2b

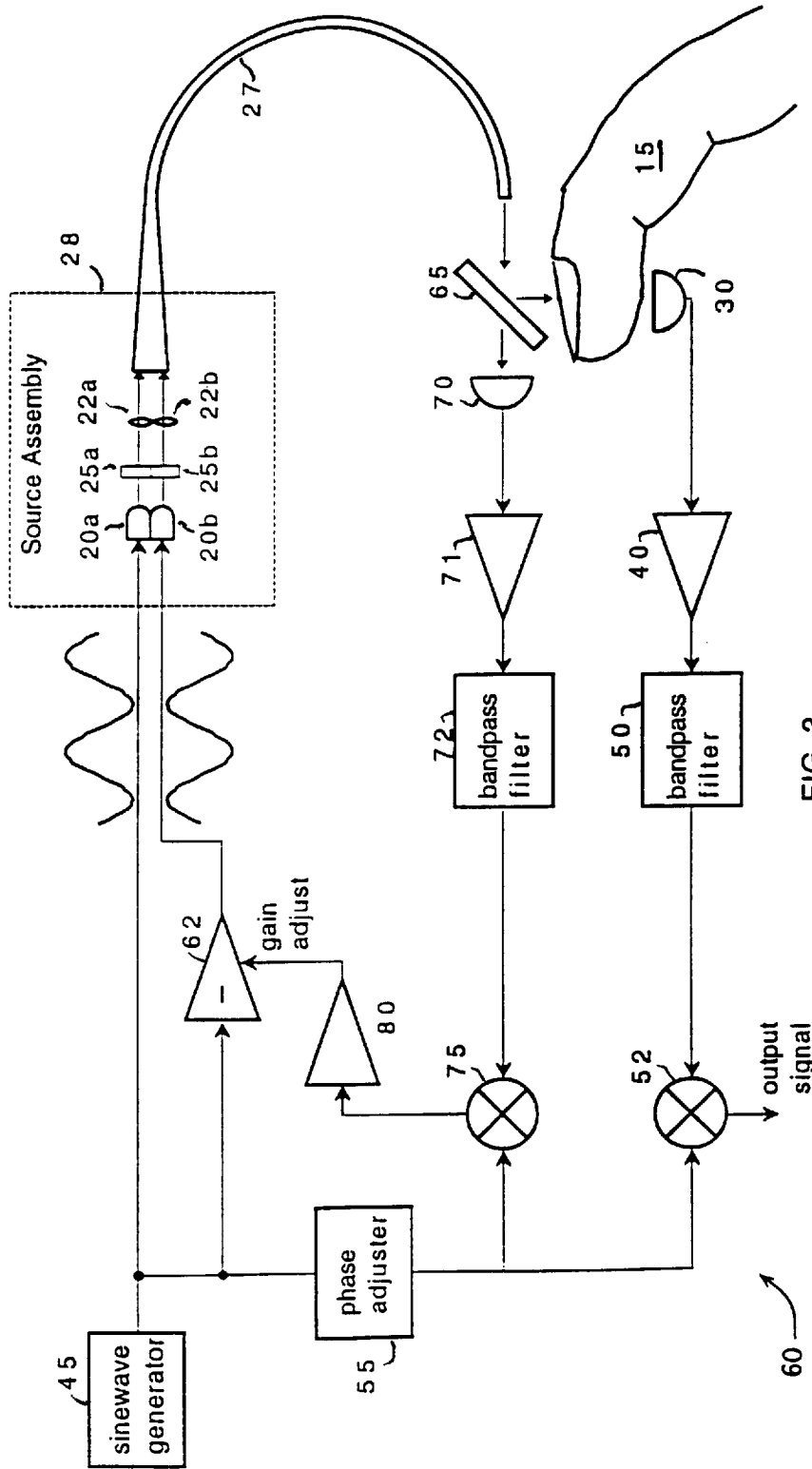


FIG. 3

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