A 90-DEGREE PHASE DIFFERENCE NETWORK FOR CIRCULAR DISPLAY OF THE EEG ON A CATHODE RAY TUBE

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For some analysis methods, which are mainly used for the study of rhythmic phenomena in the EEG, timing pulses have to be available at comparable time points of the analysed signal.

Turton (1952) and Bekkering and Storm van Leeuwen (1954) described a method for generating such pulses to trigger a photic stimulator. Timing pulses are also used in the method of automatic auto- and cross-relation analysis described by Kamp *et al.* (1965), and are generated by means of a modification of the method described by Turton. According to Turton's method, by means of a Lissajous figure, the EEG is displayed circularly on the screen of a cathode ray tube. A photo-electric device is placed on the screen of the tube and in this way a pulse is obtained whenever the spot passes the photo-electric device. The advantage of the method is that the occurrence of the timing pulses is independent to a certain degree of the amplitude of sinusoidal signals. The same applies to non-sinusoidal rhythmic signals if their wave form does not change. To obtain the circular display the signal is conducted to the horizontal and vertical deflection systems of the cathode ray tube with a 90° phase difference. The 90° phase difference is obtained only for signals within a certain frequency range and for automatic auto- and cross-relation the range of Turton's network is too limited. For this reason a 90° phase difference network described by Villard (1952), which has a wider frequency range, has been modified. This network was used for signals within the audio frequency range. By change of values of the frequency determining components the network may be used also within the EEG frequency range.

A diagram of the network is shown in Fig. 1. The complete network consists of two bridge circuits A and B which have the cathode follower output stages T_2 and T_4. The output amplitudes of the two bridge circuits are independent of the frequency of the input signal. This is not the case with the input-output phase relations. However, within a limited frequency range an approximation

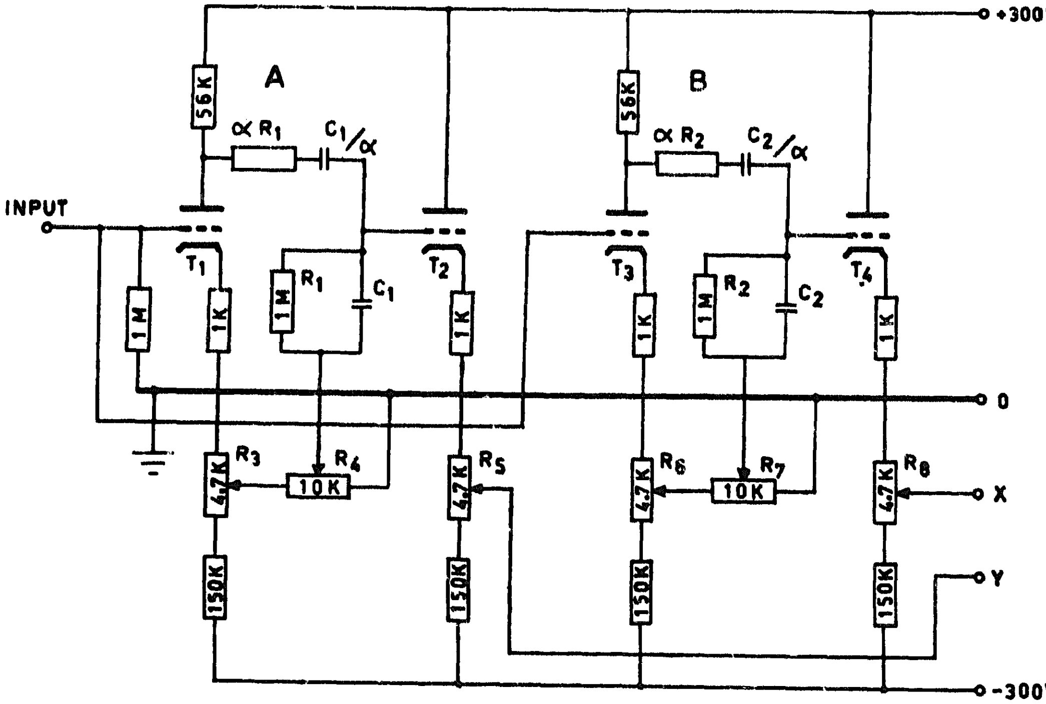

Fig. 1
Diagram of 90° phase difference network. Tubes: 6 AQ 8.

TABLE I

$\Delta\phi$ (°)	α	Ratio of frequency range	Actual frequency range	C_1/C_2
$< \pm \frac{1}{2}$	1.6	1:8	0.7 ωo_1–5.5 ωo_1	3.93
$< \pm 1$	1.8	1:12	0.6 ωo_1–7 ωo_1	4.1
$< \pm 1\frac{1}{2}$	2	1:15	0.53 ωo_1–8 ωo_1	4.35
$< \pm 2$	2	1:20	0.45 ωo_1–9 ωo_1	4.35

to 90° phase difference may be obtained between the output signals of the two bridge circuits. The frequency range and the maximum deviation from 90° phase difference are determined by the relation α between the frequency determining resistors and capacitors. For each value of α the maximum deviation from 90° phase difference and the corresponding frequency range may be calculated. For a number of values of α the deviation $\Delta\phi$ from 90° phase difference and the ratio of the corresponding frequency range are presented in Table I. The actual frequency range is expressed as a function of ωo_1 ($\omega o_1 = 1/R_1C_1$). Furthermore, for each value of α the corresponding relation C_1/C_2 is given.

By means of Table I the actual values of the capacitors of the bridge circuits may be calculated.

For example: If a deviation $\Delta\phi = \pm 2$ degrees is acceptable, the factor α is 2. This corresponds to a maximum frequency ratio of 1:20. If, for instance, a frequency range of 1.5 c/sec to 30 c/sec is desired then 1.5 c/sec corresponds with 0.45 ωo_1, thus

$$\omega o_1 = \frac{2\pi \times 1.5}{0.45} \text{rad/sec}$$

The values of the capacitors may be calculated as follows:

$$C_1 = 1/\omega o_1 R_1 \text{ Farad}$$

As $R_1 = 1$ MΩ the value of the capacitor C_1 is,

$$C_1 = \frac{45 \cdot 10^{-2}}{3\pi \cdot 10^6} \text{ Farad} \approx 0.048\ \mu\text{F}$$

With $\alpha = 2$ according to Table I, $C_2 = C_1/4.35$

Thus $C_2 \approx 0.011\ \mu$F.

The adjustment of the network is carried out in the following way:

(a) *Without input voltage*

(1) By means of the potentiometers R_3 and R_6 in the cathode leads of T_1 and T_3 the voltage across the balance potentiometers R_4 and R_7 is set at zero.

(2) By means of the potentiometers R_5 and R_8 the voltage at the output terminals x and y is set at zero.

(b) *With sinusoidal input voltage*

The balance potentiometers R_4 and R_7 are adjusted until the amplitudes of the output signals are independent of frequency.

As has been mentioned the phase relation between the output signals of the bridge circuits and the input signal is frequency dependent. Therefore, to retain the original phase relation between two signals, it is necessary to conduct the "analysed signal" to a similar network. This is the case with the auto- and cross-relation method (Kamp *et al.* 1965). To this end the bridge circuit A is duplicated. The signal to be analysed is conducted to the input of this network, and the output of the network is connected with the input of the average response computer.

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