POLARITY COINCIDENCE CORRELATOR

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The construction of a clipped correlator using a polarity coincidence multiplier is described. Subjective measurements taken indicate that the equipment is well suited for signal detection especially when the background noise level is very high.

Weak signals in a high noise background can be detected by using correlators. In the case of target detection, the accuracy of bearing determination is increased by multiplication and integration. It can be shown analytically that the directional pattern of multiplicative array has half the beam width of an additive array of the same geometry.[1]

Multiplication can be achieved in different ways. Amplitude modulation is actually a process of multiplication. Logarithmic devices can be used for multiplication by means of the relation $\log x + \log y = \log xy$. Quarter square multipliers for multiplying the quantities say x and y use squaring circuits and follow the relation $(x+y)^2 - (x-y)^2 = 4xy$. A correlator using quarter square multiplication was found to have the following limitations:

(*i*) limited input voltage range,

(*ii*) zero drift, and

(*iii*) complex adjustments.

The limitation in range may be due to the variation in δ_{gm}/δ_{eg} (where δ_{gm} is the mutual conductance of the valve and δ_{eg} the grid voltage) over the range of operation of the valve[2] and the drift owing to the inherent instability found in direct coupled amplifiers. To obviate most of these limitations, it was thought advisable to use a system in which digital technique can be adopted.

In multiplication by the method of coincidences the product of any number of inputs can be computed by making use of a theory of probability. If several events occur with a random distribution in time, the probability of simultaneous occurrence of all of them is the product of their separate probabilities. This will also be true for periodic wave forms whose periods have no common divisor. If rectangular wave forms having different periods are superimposed, the time during which the polarity of all of them being the same, will be proportional to the product of their duty ratios. This principle can be utilized by adjusting the D. C. levels of the rectangular wave forms in such a way that a valve will be turned on for the period during which all the input wave forms have the same polarity. Then the average current drawn by this valve will be a measure of the product of the input duty ratios. Thus it is apparent that digital technique can be advantageously adopted in this system and multiplication becomes independent of the characteristic of the valve used. Rosenheck has described a polarity coincidence multiplier for low frequency signals adopting digital technique[3].

PRINCIPLE OF OPERATION

The instrument consists of two channels as shown in Fig. 1. Each channel has three stages--a clipper, a comparator and an AND stage. The input wave forms are converted into rectangular wave forms of the same duration by means of the clipper and zero comparator stages taking care to see that there is no net shift in the D. C. level. Very little information will be lost by this transformation of the input signals into rectangular wave forms. Clipped signals thus obtained are multiplied by a sign multiplication process in an AND circuit. In this stage, an output is obtained whenever the input signals are both positive or both negative at the same time. The AND circuit in one channel detects the positive polarity coincidence whereas the one in the second channel detects the negative polarity coincidence of the input signals. This is accomplished by applying signals having the same polarity as the input signals to one AND circuit and the phase inverted replicas of the same to the other simultaneously. The AND stages are followed by an OR stage which gives an output whenever one of the AND circuits operates. The multiplier output is integrated over the period required and fed to a balancing circuit.

THE CIRCUIT

Fig. 2 shows the complete circuit. The clipper stage in each channel (V_1 and V_2) consists of a symmetrical differential amplifier. The zero comparators (V_3 and V_4) transform the clipped signals into perfectly squared wave forms of sufficient amplitude to operate the AND stages. The comparator used is of the double triode cathode coupled type. In the quiescent condition, the first halves of the triodes of V_3 and V_4 are conducting and the other halves cut off due to the high negative cathode bias applied. When the grid potential of the first half becomes equal to that of the second, the circuit flips. It returns to the original state when the grid potentials approach the same value again. Wave forms of opposite phases can be obtained from the two anodes of the comparator. The AND stages comprise two double triodes (V_5 and V,) which in the normal state are conducting. The valves become cut off when negative gates are applied to the grids of both the triodes simrlltaneonsly. The OR stage has two diodes (D, and D_2) connected to the cathodes of the multiplier valves in such a way that current is drawn by the cathode resistors from a battery of 22·5 volts whenever the AND stages are cut off. Only one AND stage can operate at a time. Clamping diodes V_7 and V_8 are connected to the grids of the sign multiplier for D. C. level restoration. The output of the OR stage is averaged for different time settings by means of a three way switch and RC net-worli. In order not to load the integrating circuit, a balanced cathode follower circuit (V_9) is employed for meter deflection.

The minimum voltage input required for a satisfactory functioning of the clipper stages was found to be about 1·5 volts. The grid bias necessary for proper clipping is about 50 volts positive and this should be initially adjusted by means of the potentiometers R_1 and R_2 by observing tho output wave form on an oscilloscope.

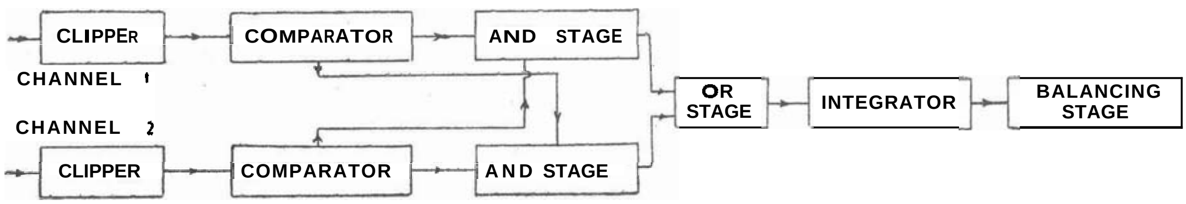

Fig. 1—Block schematic diagram of the correlator

RESULTS

Multiplier as phase meter

The multiplier can be used as a phase meter when the input signals to the two channels have the same frequency. When the two inputs are in phase, polarity coincidence will be 100% and the output meter deflection maximum. When the signals are 180° out of phase, coincidence will be zero and the deflection minimum. This provides a means of adopting a simple method for checking the calibration of the equipment. The same signal is fed to both the channels and the meter deflection corresponds to zero' degree phase shift. When the signal is fed to only one channel, the input to the other channel earthed to reduce pick up, the AND circuit will not give any output and the meter deflection corresponds to 180" phase shift.

Calibration of the equipment as a phase meter was carried out with an oscilloscope and a delay network to generate the necessary phase shift by the Lissajous figure technique. The graph obtained (Fig. 3) shows a linear relationship between phase shift and the correlator output.

PERFORMANCE OF CORRELATOR

Subjective experiment was carried out to check the overall performance of the correlator. The experimental apparatus for this method is shown in Fig. 4. White noise filtered around the signal frequency of 1·8 Kc/s by means of an octave band pass filter (1·2 to 2·4 Kc/s) was mixed electrically with the signal. The signal was fed to one channel of the correlator through a variable time delay network and the signal plus noise to the other channel through another identical delay. Each delay had 9 steps of 40μ sec. enabling nine possible positions for the signal. Fifteen observers were used and the experiment was carried out using the forced choisc method[4]. Tbe input signal to noise ratio was varied from 0 to about -25db in steps. The position of the input signal delay

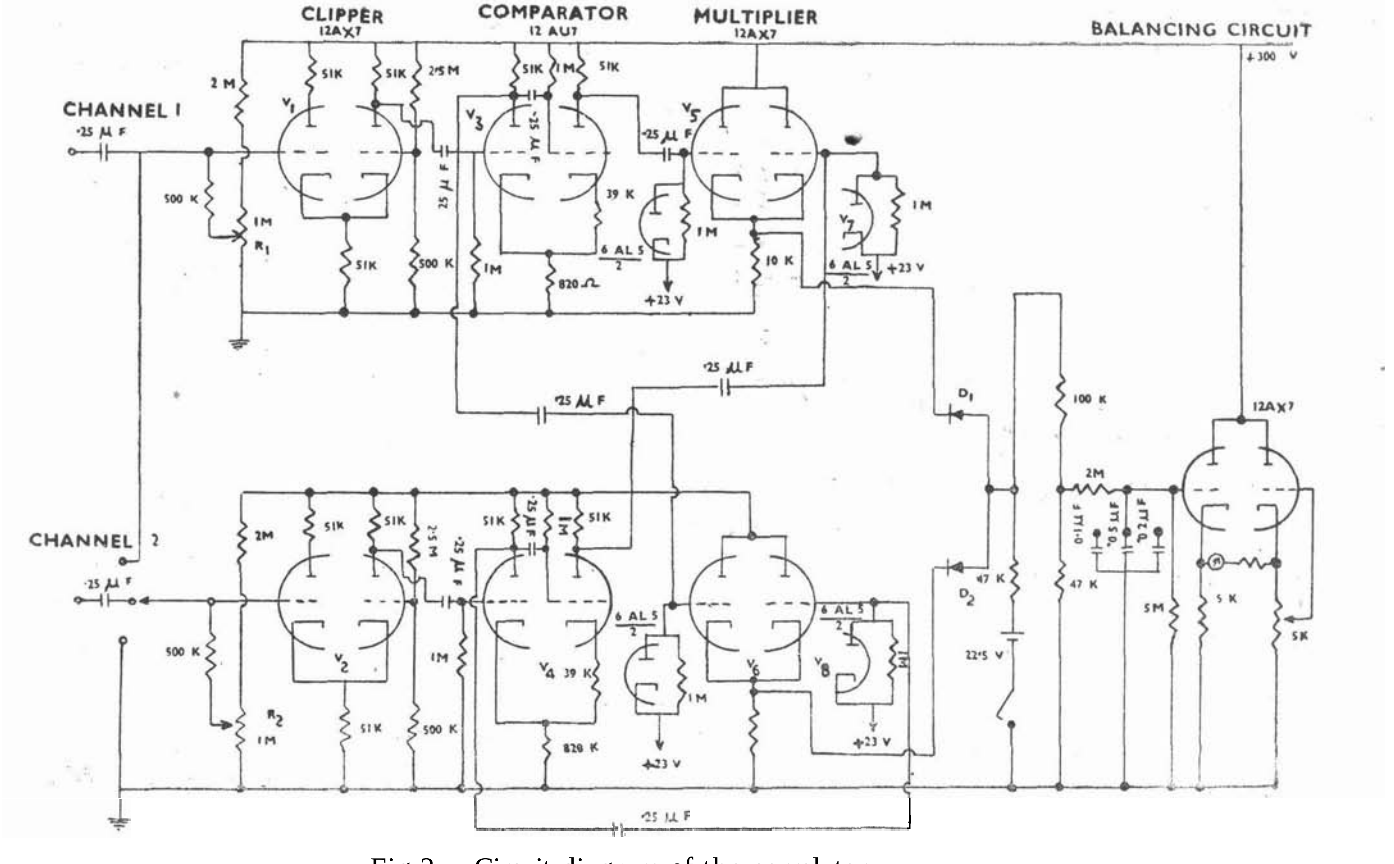

Fig 2.—Circuit diagram of the correlator.

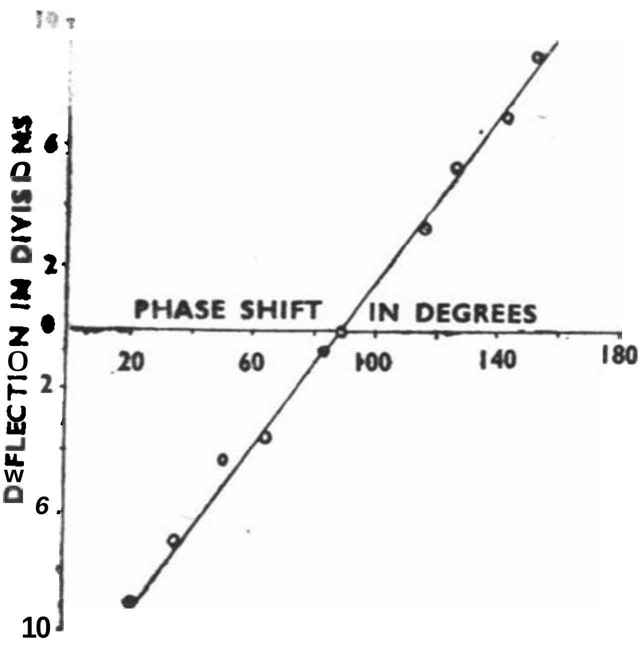

Fig. 3—Correlator as a phasemeter.

was varied at random from 1 to 9 for each S/N ratio and the observers were asked to vary the delay in the signal plus noise channel and detect the position of the delay for maximum correlator output as measured on a microammeter. No prior training in taking the readings in this experiment was given to the observers. The analysis of the data was carried out taking the mean score of all the observers as the probability of detection. The result in the graph (Fig. 5) clearly indicates that on taking 90% probability of detection as threshold, the equipment can detect a signal which has a signal-to-noise ratio of—16db.

The equipment has been functioning well and has very low drift. It requires very few initial adjustments. Reliable operation upto

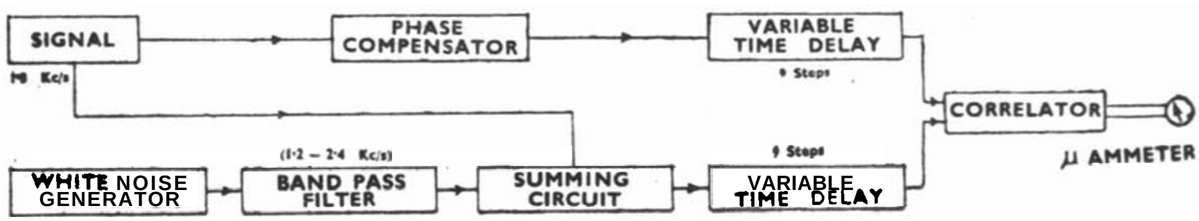

Fig. 4—Block schematic arrangement of the apparatus and test circuit in the subjective method.

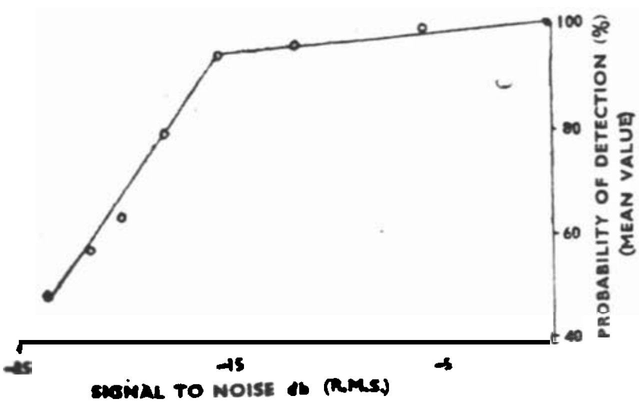

Fig. 5—Detectivity vs signal to noise db.

15 Kc/s was realised. Even though the grid bias voltages for the valves were obtained by potentiometer arrangement from the H. T. Supply, the error introduced was found to be negligible. However, for precision measurements, battery supply for the grid potential should be preferred. Laboratory measurements show that the equipment can be successfully employed in detecting weak signals in the presence of high noise background.

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