6.3 MICROWAVE PHASE COMPARATOR

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This paper presents a circuit for measuring relative phase between two microwave signals of the same frequency. The principle of phase comparison described presents no ambiguities throughout 360 degrees and is independent of relative signal amplitudes. There are no moving parts or variable phase shifters. Phase angle can be indicated automatically and instantaneously.

The phase comparator circuit comprises standard microwave components, namely two 3 db hybrids, two two-way power dividers, and two pairs of detectors. Each of the two signals whose phase difference is to be measured is divided into two equal parts and thereafter combined in the hybrids. There is a pair of detectors associated with each hybrid. By treating the difference of the detected outputs of one pair of detectors orthogonal to the difference of the detected outputs of the other pair of detectors, a single-valued function of phase for 360 degrees is obtained.

Consider the circuit of Figure 1 with input signals of amplitudes 2A, 2B, and a relative phase of ϕ degrees between the signals. Comparator I is a 180 degree hybrid (ring network) connected to the power dividers by

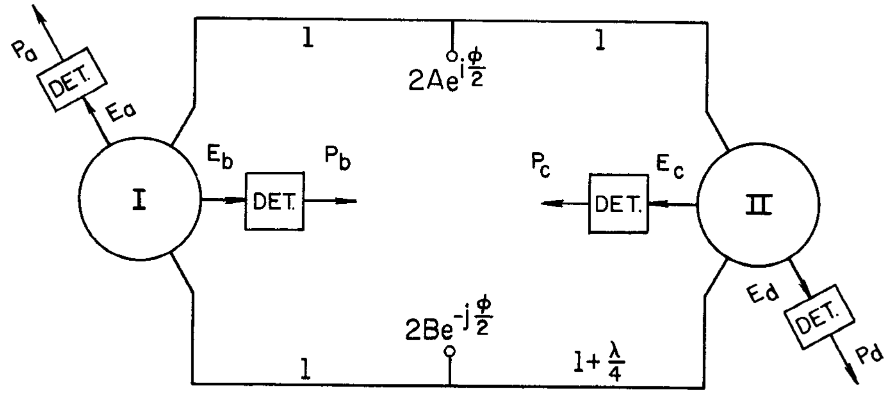

Fig. 1. Phase comparator circuit.

two equal lengths of transmission line. Comparator II is another ring network which is connected to the power dividers with two lines differing in length by one-quarter wavelength. The signal intensities at output terminals a and b of Comparator I are:

$$E_a = Ae^{j\Phi/2} - Be^{-j\Phi/2} = (A-B)\cos\frac{\Phi}{2} + j(A+B)\sin\frac{\Phi}{2} ,$$

$$E_b = Ae^{j\Phi/2} + Be^{-j\Phi/2} = (A+B)\cos\frac{\Phi}{2} + j(A-B)\sin\frac{\Phi}{2} .$$

The detected amplitudes are proportional to $|E|^2$:

$$P_a \approx |E_a|^2 = (A^2+B^2) - 2AB\cos\Phi ,$$

$$P_b \approx |E_b|^2 = (A^2+B^2) + 2AB\cos\Phi .$$

The difference of the detected amplitudes is

$$P_b - P_a \approx 4AB\cos\Phi .$$

Similarly, the detected amplitudes at output terminals c and d of Comparator II are:

$$P_c \approx |E_c|^2 = (A^2+B^2) + 2AB \sin \Phi \ ,$$

$$P_d \approx |E_d|^2 = (A^2+B^2) - 2AB \sin \Phi \ .$$

The difference of these detected amplitudes is

$$P_c - P_d \approx 4AB \sin \Phi \ .$$

Displaying these difference amplitudes orthogonally, i.e., $P_b - P_a$ along the x axis and $P_c - P_d$ along the y axis, the total power is

$$P_t \approx 4AB \cos \Phi + j4AB \sin \Phi = 4ABe^{j\Phi} \ .$$

This function is single valued over 360 degrees and has an amplitude proportional to the product of the signal amplitudes.

It may be noted that the sum of the detected signals is a quantity independent of the relative phase between the input signals.

Using the circuit shown in Figure 2 as a source of constant amplitude signals of variable phase, the detected amplitudes at the output terminals a, b, c and d of a printed microstrip version of Figure 1 were measured.

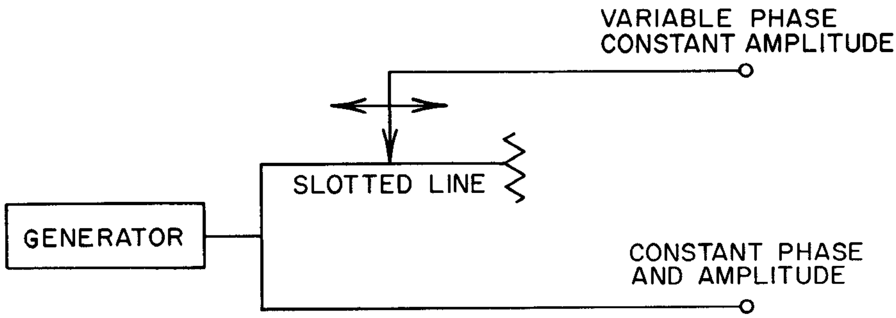

Fig. 2. Test signals source.

These measured outputs as a function of the relative phase of the two input signals are shown in Figure 3 as plotted points. A theoretical power curve is fitted over these measured values.

Figure 4 is a display obtained when $P_b - P_a$ is applied to the x axis and $P_c - P_d$ is applied to the y axis of an x-y recorder. The radials approximately every 45 degrees were obtained by stopping the probe of the slotted line at 45 degree intervals and allowing one of the signal amplitudes to go to zero. The various circles are labeled as to the difference in signal amplitudes.

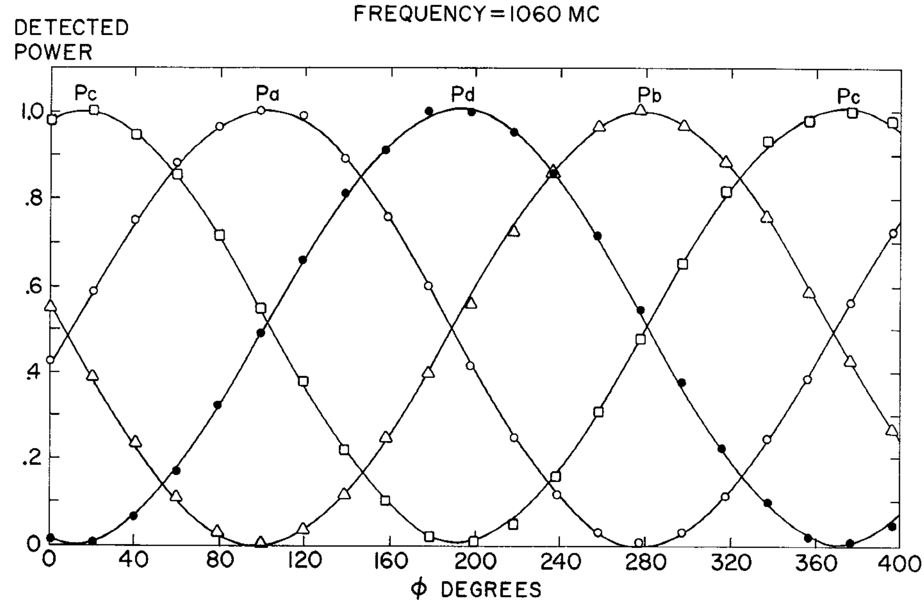

Fig. 3. Phase comparator.

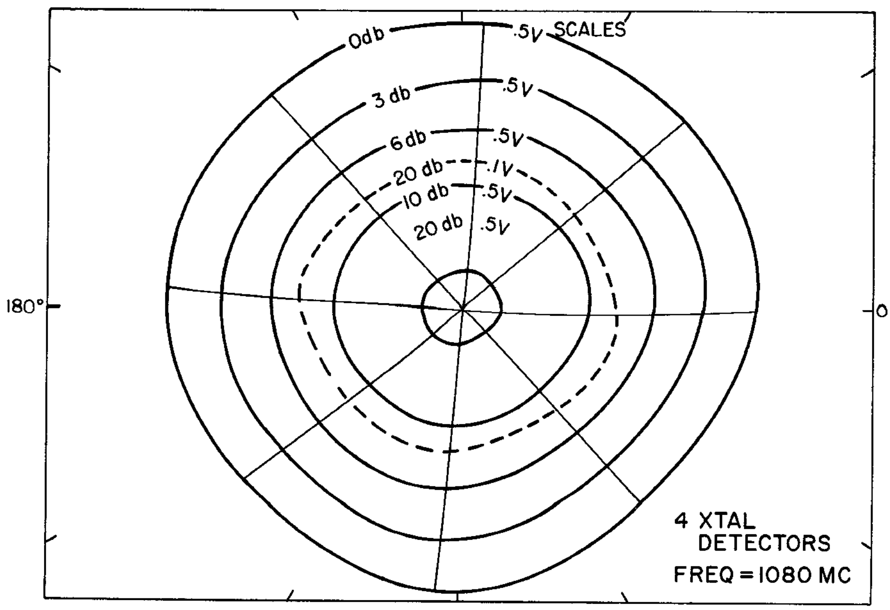

Fig. 4. Phase comparator output displayed on X-Y recorder.

The phase comparator described above has a relatively narrow frequency band because of the fixed quarter-wavelength phase shifter that is employed. A broad band version would use a 90 degree 3 db hybrid in place of the quarter-wavelength phase shifter and the associated 180 degree hybrid.