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A 180-DEGREE MICROWAVE PHASE MODULATOR (π-KEYER)

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The paper considers a reflection-type phase modulator with a phase shift of 180°, which is distinguished with its simplicity. The operation band of frequencies of the modulator is dictated by properties of the built-in *Y*-circulator or the 3-dB directed coupler. The work in the phase modulation conditions is supported with the aid of a *p–i–n* diode. The results of computer-aided simulation are included.

Microwave phase modulators find application in phased coding of transmitted signals, in shifting the carrier frequency, and as phase shifters of antenna arrays with electronic control. In the well-known Schiffman phase-shifting network, the most difficult problem is to obtain a phase shift of 180° (π) with small deviations in a wide band of frequencies. The device considered below helps resolve this problem and may be useful in any of the applications mentioned.

In order to obtain the π-phase shift, in the suggested modulator we use the known property of opposite phases of electromagnetic waves reflected from the load of the transmission line, when the load is either open-circuited ($Z_{OC} = \infty$), or short-circuited ($Z_{SC} = 0$). At $Z_{OC} = \infty$ the reflection factor of the vector $\overline{E}$ equals unity ($\Gamma = 1$) while at $Z_{SC} = 0$ it is equal to –1 ($\Gamma = -1$). After separation of the incident and the reflected waves with the aid of a *Y*-circulator or 3-dB directed coupler (3-dB DC), we obtain two possible implementations of π-keyer presented in Fig. 1.

Since the property of opposite phases of reflected waves in the open-circuit (OC) and short-circuit (SC) conditions does not depend on frequency of the signal arriving at input 1 of the keyer, as well as on the length *l* of the transmission line segments, the working range of frequencies of networks, depicted in Fig. 1, is dictated only by properties of the *Y*-circulator (Fig. 1*a*) or the 3-dB DC (Fig. 1*b*). For example, application of the Lange-type DC makes it possible to cover an octave band of working frequencies.

Realization of ideal or close to them OC- or SC-conditions of the transmission line segments is a technological problem. For almost ideal short-circuit conditions a symmetric strip line is most suitable. In the OC-conditions the segment length *l* has to be somewhat diminished — to compensate the edge capacitance of the open end. Assessment of quality of electric characteristics of the π-keyer was performed by investigation, with the aid of the MWO-2001 computer program, of the network, depicted in Fig. 1*a*, with the following initial data: a symmetric strip line with its height $b = 3$ mm, filled with dielectric with $\varepsilon_r = 2.5$ and $l = 20$ mm; an idealized circulator C with isolation 30 dB and insertion loss 0 dB; for the open-ended segment the edge effect was taken into account. The simulation results are presented in Fig. 2: at equal lengths of segments *l*, under OC and SC conditions, deviation from $\varphi = 180°$ grows gradually from 1.5° at frequency 1 GHz to 16.6° at frequency 10 GHz. When reducing the length of the open-ended segment to 19.5 mm, the deviation from 180° was within ±2° and, as shown by simulation, this deviation did not grow at frequencies up to 18 GHz. When the segments' length $l = 10$ mm, deviation from 180° corresponds to Fig. 2, and in order to keep the phase shift within 180 ± 2°, we had to reduce the OC segment to 9.6 mm.