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BASIC PARAMETERS OF NONSYMMETRICAL COPLANAR LINE

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Abstract-The wavelength of a guided wave in nonsymmetrical coplanar line on substrate with relative permittivity constant in range from 2 to 110 was measured at frequencies from 2.5 to 10 GHz. A comparison with theoretical relation calculated from simplified TEM model was done.

The nonsymmetrical coplanar line (NCL) is a novel type of microwave transmission line for microwave integrated circuits [1]. The NCL consists of a narrow metal strip - the inner conductor and of a conductive plane - the ground conductor, placed on one side of the dielectric substrate and mutually separated by a narrow slot (Fig. 1). The planar arrangement of both conductors is advantageous from the point of view of a simple connection of the components to the microwave circuit and for lowering of influence of substrate thickness to the transmission parameters of the line. The other advantages are: possibility of combination with other types of transmission lines as a slot-line [2], coplanar waveguide [3], microstrip and with a coaxial line, respectively, convenience in building the elements with gyromagnetic effect due to the existence of elliptical polarization of the guided electromagnetic wave near the slot. In comparison to the symmetrical coplanar waveguide the NCL has the advantage that there are no problems in connecting the two terminal devices as diodes, resistors, capacitors etc. paralel to the line.

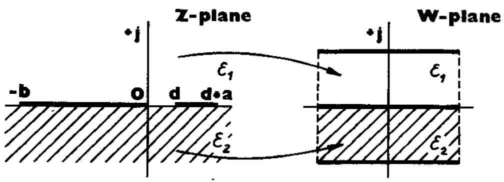

Fig. 1. Nonsymmetrical coplanar line and its conformal transformation into W-plane.

To find an analytical solution of the electromagnetic wave equation when the line is inhomogeneous, as the NCL actually is, appears to be very complicated. The problem can be simplified to the solution of a two-dimensional Laplace equation if we assume the propagation of TEM wave that is acceptable in the frequency range below critical frequencies of higher modes. In this case NCL may be analysed using conformal mapping and its characteristic impedance and relative wavelength of guided wave may be calculated. A simplified model of NCL consisting of two strips with infinite length and infinite small thickness, with infinite conductivity, placed on the boundary plane of two dielectric mediums with relative permittivities ε_1 and ε_2 is transformed in the W-plane as two strip lines parallel to each other from the point of view of the generator. Let us define the characteristic impedance of inhomogeneous NCL Z_c as a result of parallel connecting partial characteristic impedances

$$Z_{c1} = \frac{1}{\varepsilon_1}\sqrt{\frac{\mu_o}{\varepsilon_o}}\,\frac{K(k)}{K'(k)} \quad \text{and} \quad Z_{c2} = \frac{1}{\varepsilon_2}\sqrt{\frac{\mu_o}{\varepsilon_o}}\,\frac{K(k)}{K'(k)}$$

Then

$$Z_c = \frac{Z_{c1} Z_{c2}}{Z_{c1} + Z_{c2}} = \frac{1}{\sqrt{\varepsilon_1}+\sqrt{\varepsilon_2}}\sqrt{\frac{\mu_o}{\varepsilon_o}}\,\frac{K(k)}{K'(k)} \qquad (1)$$

where $K(k)$ and $K'=K(\sqrt{1-k^2})$ are complete elliptical integral of the first kind and its supplement, respectively, and the modul is

$$k^2 = \frac{1 + a/d + b/d}{(1 + b/d)(1 + a/d)}$$

If now the equivalent homogeneous NCL has the characteristic impedance equal that of inhomogeneous NCL it must be filled with material with relative permittivity $\varepsilon_e = (\sqrt{\varepsilon_1}+\sqrt{\varepsilon_2})^2/4$ and the wavelength λ_g of guided wave with the respect to the free space wavelength λ_o is

$$\frac{\lambda_g}{\lambda_o} = \frac{1}{\sqrt{\varepsilon_e}} = \frac{2}{\sqrt{\varepsilon_1}+\sqrt{\varepsilon_2}} \qquad (2)$$

and for quasi-TEM NCL is independent of both the size of conductors and frequency.

The relation (2) between relative wavelength λ_g/λ_o and relative dielectric permittivity ε_2 of the substrate, if $\varepsilon_1=1$, was experimentally verified. The samples of NCL were made by sticking a thin aluminium foil on the polished surface of substrates 50x50 mm or 25x25 mm. The width of the inner conductor 0.5 mm, parameters a/d=1 and b/d>40 were chosen. Two methods to measure the wavelength on NCL were used: the method of movable short and/or the nodal shift method. The detection probe was inductively coupled to electromagnetic field of the NCL. In Fig. 2 the theoretical relation (2) and measured values of relative wavelength λ_g/λ_o at frequencies 2.5, 3.8, 5.2, 7.5 and 10 GHz are plotted. For comparison a relative wavelength in unbounded medium with dielectric relative permittivity ε_2 and in medium with effective permittivity $(\varepsilon_1+\varepsilon_2)/2$ calculated from zero-order quasi-static approximation [4] are also indicated.

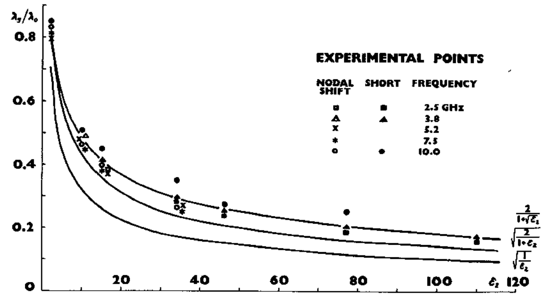

Fig. 2. Measured and theoretical values of λ_g/λ_o

The experimental verification of a simplified TEM model of the NCL by measuring the relative wavelength of a guided wave shows good agreement with a real line. The effective dielectric constant determined from equality of impedance of equivalent NCL and impedance of two parallel strip lines is more truthful than that determined from zero-order approximation. Frequence differences of experimental results can be due to errors of wavelength and substrate permittivity measurements, inadequacy of TEM model of NCL especially for higher frequencies, and influence of a thin adhesive film between conductors and substrate. This model is suitable for an initial design of a transmission line and for informative calculations of basic electrical parameters of NCL.

References

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