Letter Symbols to Designate Microwave Bands

At a recent meeting of RCRD 16 (Waveguides),[1] members discussed the question of the use of letters to designate microwave wavebands. It was noted that the use of these letters is historical, arising in the first instance from security considerations in wartime radar, and that the letters follow no logical sequence. Moreover, there is no unanimity, either in Great Britain or in the United States, as to the meaning of these letters, and there is much proliferation in some quarters, with consequent confusion. Accordingly, there appeared to be some case for dropping the existing system and either having a logical and systematic designation or, possibly, none at all. However, the members felt, despite this unpromising outlook, that the letters really did serve a useful purpose, and that some terms, such as X-band, are too ingrained to be dropped. It was suggested that these terms might be likened to the use of colors to designate parts of the optical spectrum. Although the edges of the band designated "yellow," for example, may not be too clearly defined, nevertheless it is a useful term to have; although in accurate scientific work one would naturally use the appropriate unit, Angstroms, wavenumber, or frequency. Overlap in color designation occurs, of course, and one can use phrases like yellow-green to describe them. Similarly, it was felt that with a suitable, small number of letter terms, phrases like X-band would take on a useful meaning, to be supplemented by accurate wavelength or frequency descriptions when appropriate. Terms like X-J might be used descriptively to denote overlap regions.

Although no implication of standardization, either national or international, is intended in this letter, the committee members felt it would be of value to go on record with the following agreed list of designations, and to hope that, where possible, individuals would use the letters with these meanings. The list is in substantial accord with existing usage, both in Great Britain and in the United States. The slight overlap between C- and X-bands is unfortunate, but it was felt that this was essential to maintain continuity with existing use of these letters. The recommended list is as follows.

Band	Approximate Limits (Gc)
L	1– 2
S	2– 4
C	4– 8
X	7–12
J	12–18
K	18–26
Q	26–40
V	40–60
O	60–90

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[1] United Kingdom Radio Component Research and Development Sub-Committee 16 (waveguide components).

Tangent Relation for Determining Immitance Inverter Parameters

The immitance (impedance or admittance) inverter of Cohn[1] and Matthaei[2] can be described by a tangent relation similar to that of Weissfloch.[3] The relationship leads to a simple method of extracting the inversion parameter and intrinsic angular length of a lossless, but otherwise arbitrary, discontinuity.

The immitance-inverter equivalent circuit of a section of waveguide (or transmission line) is defined by the relations illustrated in Fig. 1. Distances d_1 and d_2 are measured to the left and to the right, respectively, of the arbitrary reference plane T_0. No restriction is placed on the sign of d_1 or d_2; either or both may be negative, indicating that the prototype input or output line leading to the inverter circuit is longer than the actual line measured to T_0.

Define

$$\phi_1 = \beta_1(D - d_1) \tag{1}$$

$$\phi_2 = \beta_2(S - d_2) \tag{2}$$

where D and S are measured to the short and minimum positions, as shown in Fig. 2. Applying the transmission-line impedance formula yields

$$Z_a = -jZ_0' \tan \phi_1 \tag{3}$$

$$Z_b = jZ_0'' \tan \phi_2 \tag{4}$$

from which it follows that

$$K^2 = J^{-2} = Z_0'Z_0'' \tan \phi_1 \tan \phi_2 \tag{5}$$

or

$$k^2 = \tan \phi_1 \tan \phi_2 \tag{6}$$

where

$$k = \frac{K}{\sqrt{Z_0'Z_0''}} = \frac{\sqrt{Y_0'Y_0''}}{J}. \tag{7}$$

Eq. (7) defines the normalized inversion factor k. The Weissfloch tangent relation is[4]

$$N^2 = -\tan(\phi_1 + \theta_a) \cot(\phi_2 + \theta_b) \tag{8}$$

where θ_a and θ_b define a different pair of reference planes. It can be shown that

$$N^2 = n^2 \frac{Z_0''}{Z_0'} \tag{9}$$

where n is the turns ratio of an ideal transformer.

The plot of $\beta_1 D$ vs $\beta_2 S$ has the well-known form illustrated in Fig. 3. Points ①, ②, ③, etc., are solutions of (6) that also satisfy the equation

$$\sin 2\phi_1 = \sin 2\phi_2. \tag{10}$$

Manuscript received May 11, 1964.

[1] S. B. Cohn, "Direct-coupled-resonator filters," Proc. IRE, vol. 45, pp. 187–196, February, 1957.

[2] G. L. Matthaei, "Design of wide-band (and narrow-band) band-pass microwave filters on the insertion loss basis," IRE Trans. on Microwave Theory and Techniques, vol. MTT-8 pp. 580–593; November, 1960.

[3] A. Weissflock, "Anwendung des transformersatzes uber verlustlose vierpolen auf die hinter einander schaltung, von vierpolen," *Hochfrequenz. und Elektroak.*, vol. 61, pp. 19–28; January, 1943.

[4] N. Marcuvitz, "On the reproduction and measurement of waveguide discontinuities." Proc. IRE, vol. 36, pp. 728–735; June, 1948.

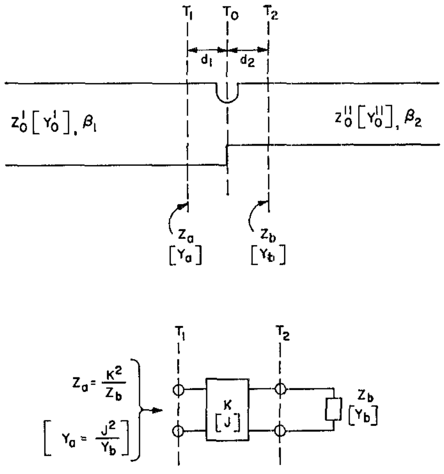

Fig. 1—Generalized waveguide discontinuity and immitance inverter equivalent circuit.

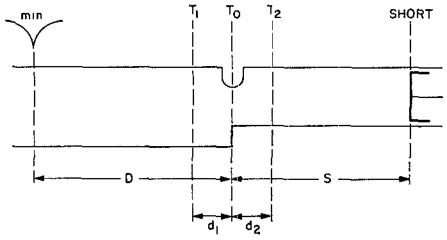

Fig. 2—Definitions of distances D, S, d_1 and d_2.

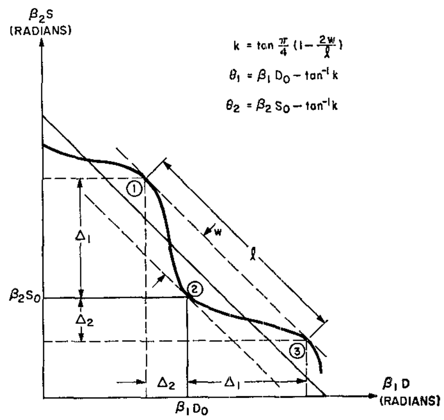

Fig. 3—Tangent relations for inversion constant and intrinsic angles derived from ϕ_1 vs ϕ_2 plot.

One of these points $(\beta_1 D_0, \beta_2 S_0)$ is identified with the relation

$$\phi_1 = \phi_2 = \tan^{-1} k. \tag{11}$$

The others lie at intervals of Δ_1 or Δ_2, where

$$\Delta_1 = \pi - 2 \tan^{-1} k \tag{12}$$

$$\Delta_2 = 2 \tan^{-1} k. \tag{13}$$

By simple trigonometry,

$$w = \frac{\Delta_1 - \Delta_2}{\sqrt{2}} \tag{14}$$

$$l = \pi\sqrt{2} \tag{15}$$