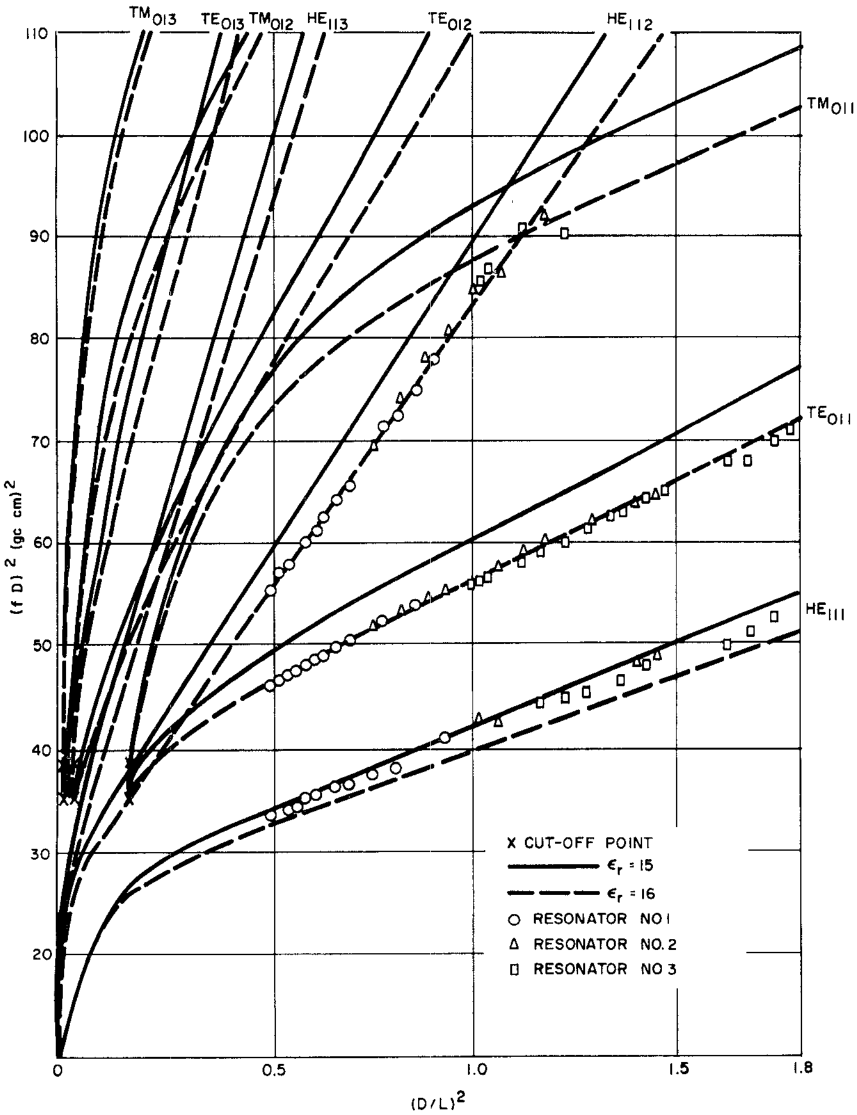

Fig. 2. Mode chart with experimental points for $MgTiO_3$.

must be determined for plotting experimental points on the dispersive characteristics shown in Fig. 1. For some experimental situations the unique representation of the mode chart is a significant advantage as less prior knowledge of the dielectric constant is needed to make reliable identification.

The experimental points were taken on resonators constructed from a magnesium titanate ceramic for which the nominal dielectric constant is 16 [8]. Data taken for each resonator are indicated by the circle, triangle or square. Successive points for each resonator were obtained by incrementally grinding the length and measuring the resonant frequency at each step. The mount used for these measurements closely resembles the parallel plate arrangement used by Hakki and Coleman [2] to measure the properties of TE modes from lower dielectric constant materials. Excitation was similarly obtained by means of an iris in one of the plates.

The most consistent results were obtained on the TE_{011} mode. This is in agreement with the suggested use of TE modes by Hakki and Coleman. It is also in agreement with the suggestion of Cohn and Kelly [6] that greatest measurement accuracy can be obtained on modes for which no electric field component exists normal to the dielectric surface. This avoids the effect of an apparent series capacity in the air gaps between the dielectric and conducting plates. The high degree of consistency for successive points for the TE_{011} mode, less than ± 0.2 per cent from a best fit curve for each resonator, suggests that a major source of the deviations was in the fabrication procedure.

Although light coupling is desirable for dielectric constant measurements, many applications require tight coupling to the resonators. On the present program, resonators have been constructed for exciting ferrite crystals from X through M band frequencies. No difficulty was encountered in achieving critical coupling in the lower order modes. Critical coupling for 0.300-inch diameter, 0.22- to 0.4-inch length posts at X band was accomplished through a 0.140-inch iris in a 0.010-inch wall.

In summary, the mode chart has been shown to be a very convenient means of mode selection and display for dielectric resonators. When used in conjunction with TE_{011} dispersive measurements, it affords a simple, accurate method of determining the dielectric constant for a wide range of dielectric values.

Acknowledgment

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D. L. Rebsch
D. C. Webb
R. A. Moore
J. D. Cowlishaw[1]
Microwave Physics Group
Westinghouse Aerospace Div.
Baltimore, Md.

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Rectangular Waveguide Flange Nomenclature

The well-known waveguide nomenclature muddle is exceeded in lack of clarity by the flange nomenclature muddle. For every rectangular waveguide size, which may have several different designations, there are several flanges available, each with its own array of designations. The flange nomenclature muddle may become a major annoyance to those users who use equipment made by different manufacturers in different countries, for manufacturers often state the flange numbers of a device without stating the waveguide size or flange nomenclature system used.

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TABLE I
LIST OF FLANGES ACCORDING TO THE FOUR MAJOR FLANGE NOMENCLATURE SYSTEMS

WAVEGUIDES		FLANGES												
IEC 153 IEC–R( )	Amer. EIA WR–( )	IEC 154 IEC–( )		British RCSC 5985–99–( )					American Armed Services (Preferred) (UG–( )/U					American EIA
				Plain			Choke		Plain			Choke		
		Plain	Choke	Brass	Alum.	Prec.	Brass	Alum.	Brass	Alum.	Prec.	Brass	Alum	Plain
3	2300	PDR3												CPR2300
4	2100	PDR4												CPR2100
5	1800	PDR5												CPR1800
6	1500	PDR6												CPR1500
8	1150	PDR8												CPR1150
9	975	PDR9												CPR975
12	770	PDR12												CPR770
14	650	PDR14		083–1573					417B	418A				CPR650
18	510	PDR18												
22	430	PDR22		083–1578					435A	437A				CPR430
26	340	PDR26		011–9656					553	554				CPR340
32	284	UER32 PDR32 PAR32 UAR32	CAR32	083–0010 083–1560 083–0058	012–2939		083–0009 083–1558		53	584		54B	585A	CPR284
40	229	UER40 PDR40		011–9657										CMR229 CPR229
48	187	PAR48 PDR48 UAR48 UER48	CAR48	083–0042			083–0041		149A	407		148C	406B	CMR187 CPR187
58	159	PAR58 PDR58 UAR58 UER58	CAR58	082–1602	083–0129									CMR159 CPR159
70	137	PAR70 PDR70 UAR70 UER70	CAR70	083–0038	083–0132		083–0037	083–0131	344	441		343B	440B	CMR137 CPR137
84	112	PBR84 PDR84 UBR84 UER84	CBR84	011–9660 083–0034	012–0892 011–9112		011–9661 083–0033	012–0893 083–0134	51	138		52B	137B	CMR112 CPR112
100	90	PBR100 PDR100 UBR100 UER100	CBR100	083–0004 083–0052	083–0151 083–0148		083–0003 083–0051 083–1611	083–0150 011–0114 012–0891	39	135		40B	136B	CMR90 CPR90
120	75	PDR120 UER120												
140	62	PBR140 PDR140 UBR140 UER140	CBR140	083–0030 011–9660			083–0029 011–9663		419			541A		
180	51	UER180 PDR180		011–9664			011–9665							
220	42	PBR220 UBR220 PCR220	CBR220	011–9666 011–9658			011–9667 011–9659		595	597		596A	598A	
260	34	PCR260												
320	28	PBR320 PCR320 UBR320	CBR320	083–0018 012–4834		083–1553	012–4835		599		381	600A		
400	22	PCR400		011–9668		083–1553					383			
500	19	PCR500 PAR500		083–0026		083–1554								
620	15	PCR620 PFR620		083–1613		083–1554					385			
740	12	PCR740 PFR740		083–0061		083–1554					387			
900	10	PCR900 PFR900				083–1554								
1200	8	PCR1200 PFR1200				083–1555								
1400	7					083–1555								
1800	5					083–1555								
2200	4					083–1555								
2600	3					083–1555								

Flanges classified under the International Electrotechnical Commission, British RCSC, American Armed Services, and American EIA nomenclature systems are listed in Table I. The numbers tabulated along with the publications referenced will serve to identify the majority of flanges currently in use. It is unfortunate, but true, that flanges fitting the same waveguide size, but belonging to different nomenclature systems, may not mate. In case of doubt, the publications listed below should be consulted for precise mechanical details.

The International Electrotechnical Commission system [1] comprises numbers "154 IEC-( )" containing, in sequence, the following information: 1) "*P*" for pressurizable, "*C*" for pressurizable choke, or "*U*" for unpressurizable; 2) *A*, *B*, *C*, *D*, *E*, or *F* to denote the appropriate mechanical features; and 3) the number of the IEC waveguide with which the flange is used.

The British RCSC system [2] comprises catalog numbers "5985-99-( )" which contain no information concerning the flange type or construction.

The Armed Services preferred flanges are those "UG-( )/*U*" flanges recommended for use in new equipment. The numbers contain no information on flange type or construction. Preferred flanges and other RF equipment is listed in a handbook [3].

The EIA system [4] comprises numbers which contain, in sequence, the following information: 1) "*C*" for connector, 2) "*M*" for miniature contact or "*P*" for pressurizable contact; 3) "*R*" for rectangular waveguide; 4) number of the EIA waveguide with which the flange is used.

It is encouraging to note that some groups favor a reduction in the total number of designations; Germany's DIN group has begun to adopt the IEC nomenclature system [5]. Convenience dictates that such a change is not possible for all presently-used systems. It is suggested, however, that all specifications should carry the IEC designation in addition to any other system used For example: "The instrument uses RG-39/U (similar to and will mate with 154 IEC-UBR 100) flanges."

M. Michael Brady
Norwegian Defence Research Est.
Kjeller, Norway

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Optimum Design of Helix Couplers with Shielding

Helix couplers have to be shielded to insure good match to coaxial cables. In our calculations the effect of the shielding has also been taken into consideration. As a result of this, the calculated dimensions of helix couplers approximate more closely the best experimentally obtained ones.

The calculation is based on simplifying assumptions. The real helix is substituted by a helically conducting cylindrical tube of infinite length and zero thickness. The effect of the dielectric materials is neglected.

In computing the coupling factor, the effect of shielding should also be taken into account. Then, as an approximation the shield itself is also regarded as a helically conducting surface. In this way three coupling factors can be calculated. The resulting coupling factor is given by [1]

$$k = k_{1,2}\sqrt{\frac{1 - k_{2,3}^2}{1 - k_{1,3}^2}} \tag{1}$$

where $k_{1,2}k_{1,3}$, and $k_{2,3}$ are the coupling factors between the inner helix and coupling helix, the inner helix and shield, and the coupling helix and shield, respectively.

If the phase velocities along the helices are equal, the coupling factors are obtained as [2]

$$\left.\begin{aligned} k_{1,2} &= e^{-\beta(a_2-a_1)} \\ k_{1,3} &= e^{-\beta(a_3-a_1)} \\ k_{2,3} &= e^{-\beta(a_3-a_2)} \end{aligned}\right\} \tag{2}$$

where β is the common phase constant of propagation along coupled helices, a_1 is the mean radius of inner helix, a_2 is the mean radius of coupling helix, a_3 is the inner radius of the shield. The coupling phase constant for synchronous helices is [2]

$$\beta_c = 2\beta k. \tag{3}$$

Hence the coupling wavelength is

$$\lambda_c = \frac{2\pi}{\beta_c} = \frac{\pi}{\beta k} \cdot \tag{4}$$

In order to completely transfer the power, the length of the coupling helix must be equal to half of the coupling wavelength λ_c.

To arrive at an optimum dimensioning of helix couplers, let us examine the relation between the coupling phase constant and the phase constant of the propagation along an uncoupled helix. This will, at the same time, give the approximate frequency dependence of the coupling phase constant, as the phase constant along a single helix is proportional to the frequency.

The inner radius of the shield can be expressed as

$$a_3 = a_2 + h \tag{5}$$

where h is the mean distance between the coupling helix and its shield.

The relation between the coupling phase constant and the single helix phase constant is obtained by substituting (1) and (2) into (3) and taking into account (5).

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Then we get

$$\beta_c = 2\beta e^{-\beta(a_2-a_1)}\sqrt{\frac{1 - e^{-2\beta h}}{1 - e^{-2\beta(a_2-a_1+h)}}} \cdot \tag{6}$$

It is more advantageous to have this equation written in a dimensionless form. To this end both sides of the equation are multiplied by a_1 and the exponents are transformed with the result

$$\beta_c a_1 = 2\beta a_1 e^{-\beta a_1((a_2/a_1)-1)} \sqrt{\frac{1 - e^{-2\beta a_1(h/a_1)}}{1 - e^{-2\beta a_1((a_2/a_1)-1+(h/a_1))}}} \cdot \tag{7}$$

Equation (7) includes two parameters; a_2/a_1 is the ratio of the mean radius of the coupling helix to that of the inner helix; h/a_1 is the ratio of the mean distance between the coupling helix and its shield to the inner-helix mean radius.

Figure 1 shows the dependence of $\beta_c a_1$ on βa_1 for different h/a_1 values, with $a_2/a_1 = 2$. The curve with $h/a_1 = \infty$ corresponds to the case when the coupling helix is not shielded. The remaining curves indicate the effect of shielding. It is to be seen from this figure that taking into account the effect of the shield a lower value is obtained for β_c; that gives a longer coupling helix as compared to that obtained when the effect of the shield is neglected. Consequently, a better agreement with the experimental results is attained if the effect of the shield is taken into account [3].

In the vicinity of the maximum the coupling phase constant has a nearly constant value over a wide band as seen in Fig. 1. Therefore, the maximum of the curve

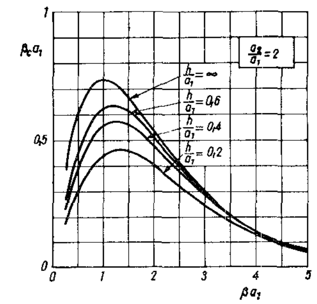

Fig. 1. Coupling phase constant as a function of the single-helix phase constant for different h/a_1 values, with $a_2/a_1 = 2$.

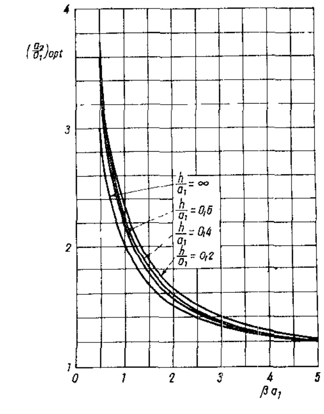

Fig. 2. Optimum a_2/a_1 ratio as a function of the single-helix phase constant for different h/a_1 values.