Nov. 30, 1965 J. D. MILLER 3,221,206

OUTPUT WINDOW AND COUPLER FOR HIGH FREQUENCY ELECTRON DISCHARGE DEVICE

Filed Feb. 21, 1964 2 Sheets-Sheet 1

FIG. 1

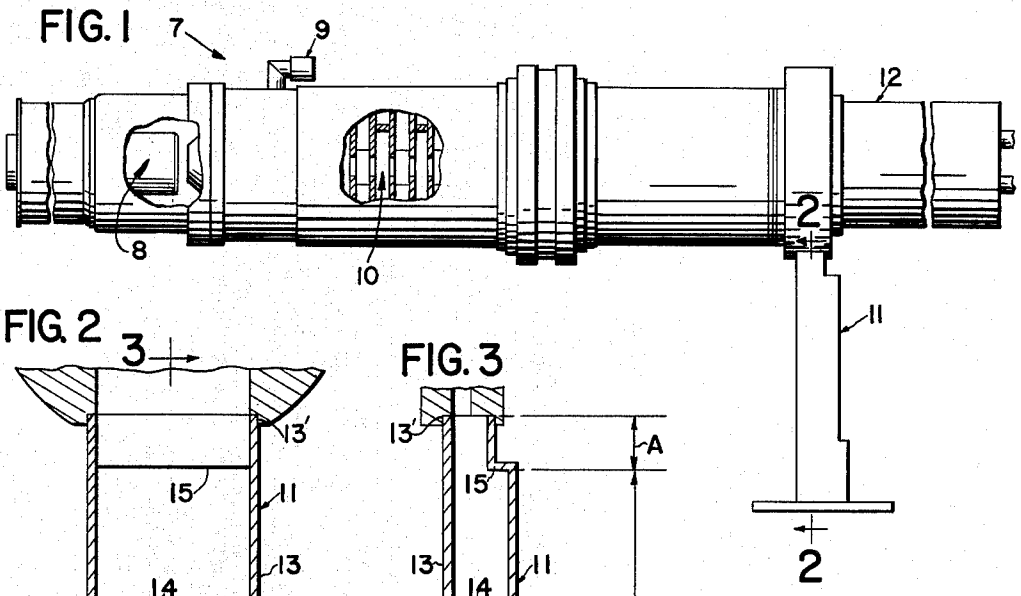



FIG. 2

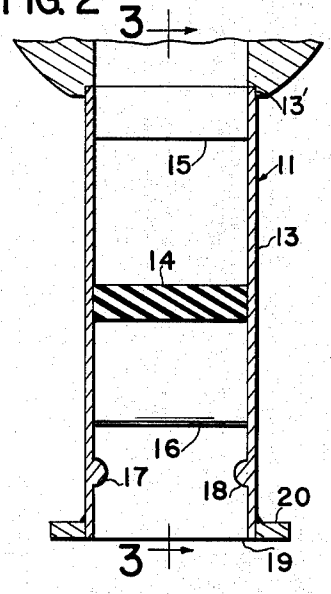



FIG. 3

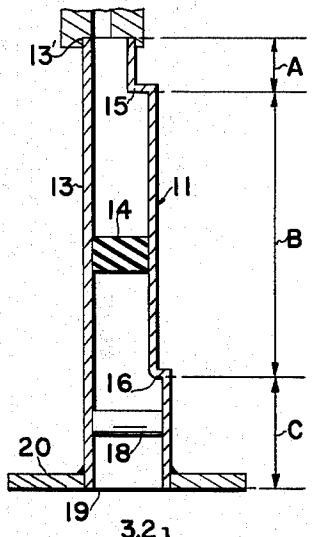



FIG. 4

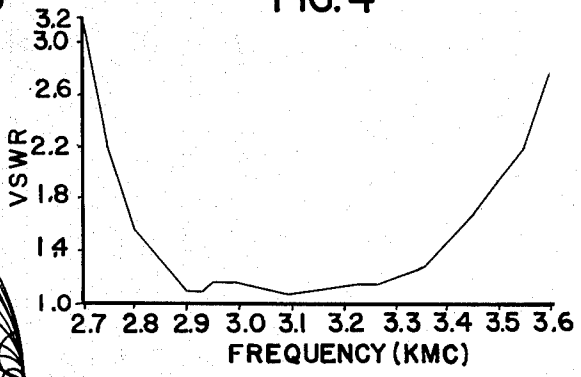
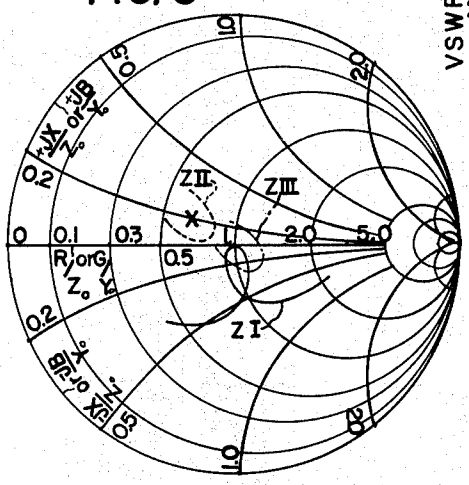



FIG. 5




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OUTPUT WINDOW AND COUPLER FOR HIGH FREQUENCY ELECTRON DISCHARGE DEVICE

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FIG. 6

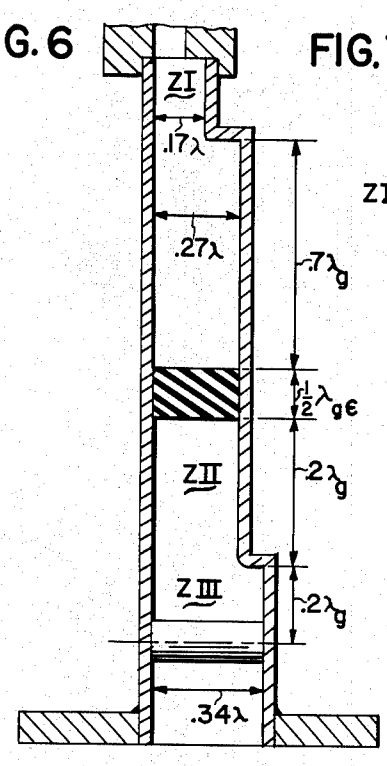



FIG. 7

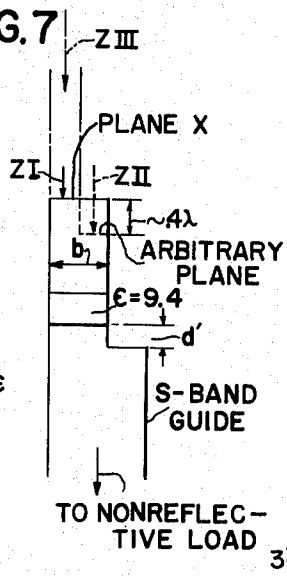



FIG. 9

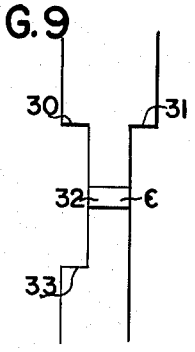



FIG. 10

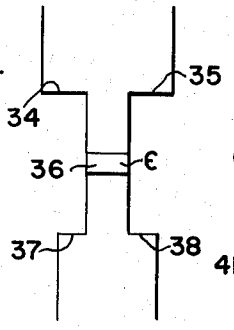



FIG. 11

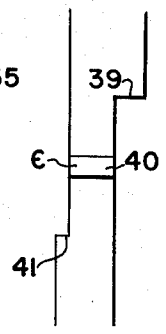
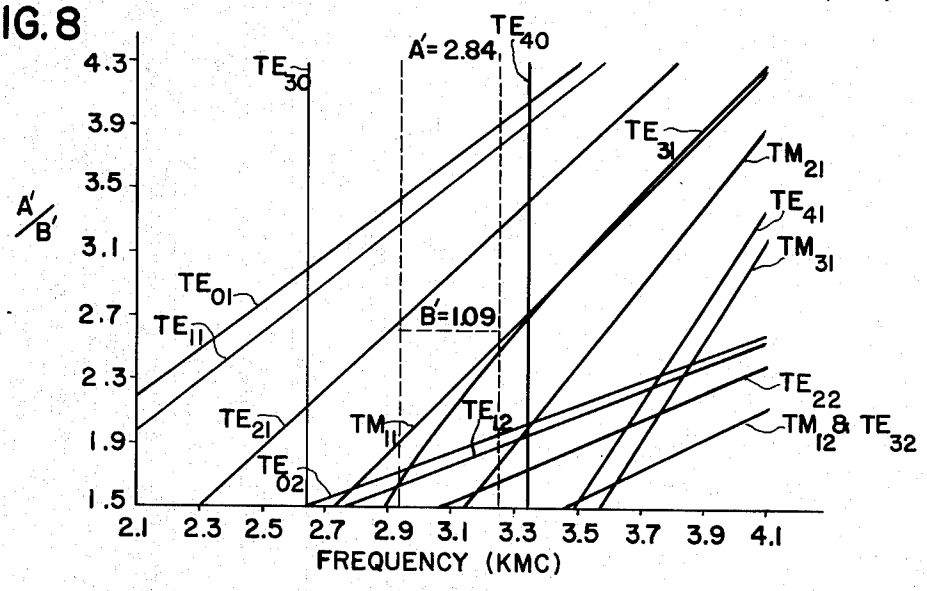



FIG. 8




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3,221,206

# OUTPUT WINDOW AND COUPLER FOR HIGH FREQUENCY ELECTRON DISCHARGE DEVICE

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Filed Feb. 21, 1964, Ser. No. 346,530
17 Claims. (Cl. 315—3.5)

This invention relates in general to the field of high frequency electromagnetic transmission and more particularly to high frequency electron discharge devices and electromagnetic energy transmission means therefore.

Present state of the art electron discharge devices are under continuous development with the trend of development being higher power, higher frequency, broader bandwidth, increased transmission efficiency and simplification of overall design. Such high frequency electron discharge devices as the traveling wave tube, klystron and magnetron are typical examples of the aforementioned devices which are presently undergoing extensive investigation with the intention of improving the aforementioned characteristics thereof. One of the major stumbling blocks in attempting to build an improved high frequency electron discharge device of the aforementioned types is the electromagnetic wave energy couplers utilized to transfer electromagnetic energy both to and from the device through differential vacuum conditions and differential impedance conditions. In particular with the advent of higher powers serious problems are encountered by the tube designer in providing adequate means for transmission of the electromagnetic wave energy from these devices without appreciable sacrifices in bandwidth and efficiency of transmission. Furthermore, at high power levels electrical breakdown phenomena and overheating of the transmission device couplers, in particular the electromagnetic wave permeable window portions of said couplers and the presence of spurious modes, hereinafter termed ghost modes, in said window portions, present a formidable array of problems which must be considered and overcome.

In addition to the aforementioned design problems, the ever present necessity of minimizing cost and attempting to simplify and generalize the design to provide a solution to a wide variety of conditions must be dealt with.

The present invention provides what is considered a novel solution to the aforementioned design criteria which results in improved high frequency electron discharge devices of the aforementioned types and which further results in a novel transmission coupler for high frequency electromagnetic energy.

The present invention provides the aforementioned solution in the following manner. Starting with the basic conditions of providing high frequency electromagnetic transmission coupler means between two points which are characterized by having differential vacuum and differential impedance characteristics therebetween, the problem involves transferring electromagnetic energy between said points, while attempting to minimize loss of energy, narrowing of the transmission bandwidth, and introduction of ghost modes or other types of distortions. A low loss wave permeable vacuum window of the block type disposed within a hollow waveguide has been found to best satisfy the criteria of low transmission loss at high power levels in the multi-megawatt region while maintaining structural integrity during use. However, it has been determined that the block window is essentially a narrow band device and therefore means have to be provided to broadband the coupler means as well as to provide an optimum impedance transformation between the source and the load points.



The present invention provides a novel solution in the form of a compact high frequency electromagnetic wave transmission coupler having a pair of E-plane impedance discontinuities within the coupler and a block window disposed therebetween. The window is preferably a half wavelength long (thick) at the center of the operating frequency of the pass band which it is desired to transmit. To enhance the final match an inductive iris is positioned within the coupler. The aforementioned coupler has been found capable of transmitting peak powers in excess of 6 megawatts and average powers in excess of 15 kilowatts without substantial reflection or introduction of ghost modes within the desired pass band while effecting impedance transformations between source and load points differing by, for example, 2–1 ratios and greater.

It is therefore an object of the present invention to provide an improved electron discharge device having novel electromagnetic wave transmission coupler means therefore.

A feature of the present invention is the provision of a high frequency electron discharge device having electromagnetic wave transmission coupler means which include a wave permeable block window disposed within a waveguide with an E-plane impedance discontinuity disposed on each side of said block window.

Another feature of the present invention is the device set forth in the aforementioned feature wherein said window is dimensioned to be substantially $n/2\lambda_{g_e}$ long where substantially includes $\pm 1/12\lambda_{g_e}$ as measured at the center frequency of the pass band to be transmitted therethrough where $n$ is any positive integer.

Another feature of the present invention is the provision of an inductive iris disposed within the coupler as defined in the aforementioned feature wherein said inductive iris is spaced from one of said E-plane impedance discontinuities.

Another feature of the present invention is the provision of a high frequency electron discharge device havig a broadband output electromagnetic wave energy transmission coupler comprising a rectangular waveguide with a block window disposed therein and an E-plane discontinuity disposed on each side of said window, said E-plane discontinuities having impedance characteristics and displacements from said window such that electromagnetic energy reflections within said coupler are minimized while simultaneously broadbanding said window for said coupler design.

Another feature of the present invention is the provision of a high frequency, broadband, high power, electromagnetic wave transmission coupler capable of maintaining a differential vacuum between the respective transmission ends thereof which coupler includes a wave permeable block window disposed in vacuum sealed relation within a waveguide, said waveguide having an E-plane impedance discontinuity disposed on each side of said window, said E-plane discontinuities having impedance characteristics and displacements from said window such that electromagnetic wave energy reflections within said coupler are minimized while simultaneously broadbanding said window for said coupler design.

Other features and advantages of the present invention will become more apparent upon a perusal of the following specification taken in conjunction with the accompanying drawings wherein,

FIG. 1 is a perspective view of a high frequency high power traveling wave tube and electromagnetic wave energy transmission coupler means therefore.

FIG. 2 is an enlarged cross-sectional plan view of the transmission coupler taken along the lines 2—2 of FIG. 1 in the direction of the arrows.

FIG. 3 is a cross-sectional view of the transmission

coupler taken along the lines 3—3 of FIG. 2 in the direction of the arrows.

FIG. 4 is a graphical portrayal of V.S.W.R. vs. frequency for a transmission coupler designed according to the teachings of the present invention.

FIG. 5 is a simplified version of a standard Smith Chart wherein a method of designing the coupler of the present invention is outlined.

FIG. 6 is an enlarged cross-sectional view of a coupler designed according to the teachings of the present invention to cover a specific band of frequencies.

FIG. 7 is a schematic representation depicting the intermediate and final design stages of a coupler built according to the teachings of the present invention.

FIG. 8 is an illustrative graphical plot of aspect ratio vs. mode frequency for a block window such as utilized in the present invention.

FIG. 9 is a schematic representation of an alternative embodiment of the present invention.

FIG. 10 is a schematic representation of an alternative embodiment of the present invention.

FIG. 11 is a schematic representation of an alternative embodiment of the present invention.

Referring now to the drawings there is shown in FIG. 1 a high frequency electron discharge device **7** of the traveling wave type which is exemplary of the types of electron discharge devices which are enhanced through the utilization of the transmission coupler of the present invention. For the details of the traveling wave tube of the type such as depicted in FIG. 1 see U.S. patent application Serial Number 56,415 by J. A. Ruetz et al., filed September 16, 1960, and assigned to the same assignee as the present invention. Other typical examples of high frequency electron discharge devices wherein the transmission coupler of the present invention can advantageously be employed are such as, for example, those depicted in U.S. Patents 2,915,670; 2,928,972; 2,963,616; 3,028,519; and 3,096,462.

The traveling wave tube of the type depicted in FIG. 1 includes a beam forming and projecting portion or electron gun means **8**, R.F. input coupler **9**, slow wave electromagnetic interaction circuit portion **10**, R.F. energy transmission output coupler **11** and collector means **12** which are interrelated in a vacuum sealed relationship.

In FIG. 2 an enlarged cross-sectional view of the transmission coupler **11** is shown and includes rectangular waveguide **13** having the one end thereof **13'** brazed in vacuum sealed relationship to a main body portion of the device envelope as shown. An electromagnetic wave permeable low loss block window **14** is vacuum sealed within the waveguide by any suitable ceramic to metal braze or the like. Spaced from said window on each side thereof are E-plane impedance discontinuities **15, 16** as best seen in FIG. 3. A set of inductive irises **17, 18** are positioned in the waveguide **13** in spaced relation from the E-plane impedance discontinuity **16** as shown. The other load or external end portion **19** of the coupler **11** preferably terminates at a coupler flange **20** as shown. The waveguide portion **13** of the coupler **11** is characterized by having three sections A, B, C, respectively wherein each of said sections has different height dimensions $b$, and identical width dimensions $a$. Since the coupler **11** is designed to handle high powers all edges at the discontinuities, both E and H plane types, are preferably rounded to minimize the possibility of arcing.

The following relationships and definitions are presented to illustrate and define the physical and electrical parameters of a high power broadband coupler designed according to the teachings of the present invention.

Since free space wavelength $\lambda$ is defined as follows:

$$\lambda = c/f$$

where $c$=velocity of light
and $f$=frequency

and the waveguide wavelength $\lambda_g$ for a rectangular guide for the $TE_{10}$ mode is defined as

$$\lambda_g = \frac{\lambda}{\sqrt{1-\left(\frac{\lambda}{2a}\right)^2}}$$

for air or vacuum and

$$\lambda_{g\epsilon} = \frac{\lambda}{\sqrt{\epsilon-\left(\frac{\lambda}{2a}\right)^2}}$$

for window portion where $\epsilon$=dielectric constant of the medium (window) filling the guide $\epsilon$=1 for air, and $a$=waveguide width, and rectangular waveguide impedance Z for the $TE_{10}$ mode is defined by

$$Z = 377\frac{\lambda_g}{\lambda}\frac{\pi}{2}\frac{b}{a}$$

where $b$=waveguide height. The following impedance parameters were successfully matched at S Band for the coupler depicted in FIGS. 1-3 having the physical and electrical parameters set forth in terms of $\lambda$, $\lambda_g$ and $\lambda_{g\epsilon}$ in FIG. 6 at a center frequency $f_0$ of the passband $\simeq$ to 3.1 kmc. with the following waveguide relationshps

$$\frac{\lambda_g}{\lambda} \simeq 1.39 \text{ and } a \simeq \frac{\lambda_g}{2}$$

and the block window is alumina ceramic having a dielectric constant $\epsilon \simeq 9.4$

$$Z_I \simeq 210\Omega$$
$$Z_{II} \simeq 320\Omega$$
$$Z_{III} \simeq 390\Omega$$

This design was found capable of handling average powers of about 15 kilowatts and peak powers of above 6 megawatts without electrical breakdown occurring within the guide while achieving good V.S.W.R. levels over a fairly wide passband as evidenced by the characteristics depicted in FIG. 4. It is seen upon examination of FIG. 4 that the coupler design as set forth above achieved V.S.W.R.'s of less than 1.15 in the band from approximately 2.890 kmc. to 3.280 kmc. The more impressive features of this invention lie in the realization that the R.F. coupler of the present invention is capable of handling high powers without appreciable loss in the passband through the combination of a block window and E-plane impedance discontinuities which perform a duel function of simultaneously providing a smoooth substantially reflectionless impedance transformation between differential impedances while broadbanding an otherwise narrow band block window disposed intermediate said E-plane impedance discontinuities. Quite obviously the present invention provides an extremely simple solution to the problem of transferring electromagnetic wave energy between points having differential impedance and vacuum levels. It is also apparent that the present invention can transform energy between high and low impedance levels as well as between low and high impedance levels as set forth hereinabove and hereinafter.

A design method such as set forth in the Smith Chart of FIG. 5 is advantageously employed to provide a generalized design approach for the microwave spectrum for a given set of differential impedance values when using the combination of a block window with E-plane impedance discontinuities disposed on each side of said window. For an explanation of the utilization of the Smith Chart of the type depicted in FIG. 5 see any standard microwave text. Suffice it to say that once the combination of block window and E-plane impedance discontinuities as set forth above has been chosen by the designer regardless of whether the choice of this combination was dictated by intuitive reasoning, system physical limitations or for any other reason the following design approach can be utilized to set the electrical and physical parameters of the coupler of the present invention for a given set of

differential impedance values between what can be termed the load and source points over which the electromagnetic wave energy is to be transferred.

The block window will preferably be $\frac{1}{2}\lambda_{g_e}$ at the center of the band of frequencies which it is desired to pass. However, it has been determined that the window can be $n/2\lambda_{g_e}$ wherein $n$ is any positive integer and that it can vary in length +30% of any multiple of $n/2\lambda_{g_e}$, where $n$ is any positive integer as determined at the center of the passband and still handle multi-megawatt peak powers with good bandwidth and fairly smooth impedance transformation between source and load. The dimensions of the output or load end **19** of the rectangular guide are predicated on the system load requirements which in the embodiment of FIG. 1–3 is a standard S-Band guide. The dimensions of the input or source end **13'** of the rectangular guide are predicated to a certain extent on the impedance present at the source which for purposes of explanation can be stated here as being the impedance value presented at the transmission line output portion of the electron discharge device.

The exact physical and electrical parameters chosen for the block window and the waveguide parameters of the coupler can now be determined with the aid of a Smith Chart once the basic combination of a block window and a pair of E-plane discontinuities has been preselected. The first step in the design procedure would be the selection of a suitable material for the block window. There are many commercially available materials having low loss and low dielectric constant parameters which could advantageously be employed such as, for example, fused quartz, beryllia ceramic, (BeO), alumina ceramic, single crystal sapphire, etc. For purposes of illustrating a specific embodiment alumina ceramic will be employed. The dielectric constant of alumina cermic ($Al_2O_3$) is $\simeq$9.4. In order to obtain a good impedance match between the source and load portions coupled with good bandwidth and to avoid the aforementioned ghost modes in the passband of the window various combinations of window lengths, widths, and heights or aspect ratios ($A'/B'$) of the window can be selected in conjunction with different combinations of E-plane discontinuities. The available combinations which would provide reasonable solutions could conceivably approach astronomical numbers. Therefore, one can simplify the design by preselecting a window of a given length (thickness) such as, for example, $\frac{1}{2}\lambda_{g_e}$ and of a given aspect ratio which in this case determines the waveguide width and height dimensions for guide section B.

The selection of the window dimensions and thus the waveguide dimensions of Section B are thus predicated on such factors as; the desired mode-free bandwith; frequency range of interest such as S-Band, X-Band, etc.; lowest feasible electric field gradients for frequency range of interest; power handling capability of ½ wavelength block window size. Reference is made to the following article for a discussion of ghost modes which is one of the aforementioned factors in determining the Section B waveguide dimensions as well as the block window dimensions of width, height and thickness: I.R.E. Transactions on Microwave Theory and Techniques, vol. M TT–8, No. 2, March 1960, "Resonant Modes in Waveguide Windows," by M. P. Forrer and E. T. Jaynes.

It is possible to write an analytic set of equations, derived from transmission line and filter theory considerations, to describe a window assembly in terms of the ceramic and any other arbitrary linear, passive matching elements.

Such an approach in general leads to a set of transcendental or otherwise cumbersome equations which often take longer to solve analytically for a specific design than to obtain similar results by judicious use of the Smith impedance plot.

In the case of the block window, a "mode search" was first made for an alumina block geometry in the frequency band of interest. By inspecting a mode frequency versus aspect ratio computation similar to that shown in FIG. 8, an aspect ratio was chosen to give reasonable mode clearance for as high a guide height (lower field gradient) as possible. For an alumina block with relative dielectric constant of $\simeq$9.4 and cut to operate at 3.1 kmc., computation of the first order even modes showed that the bandwidth available was better than 14% using an aspect ratio of 2.63. Normal aspect ratio of WR 284 S-Band waveguide is 2.12. The range of frequencies over which mode clearance was precalculated was from approximately 2.85 to 3.27 kmc. Ordinarily the block would be cut to be $\lambda_{g_{e/2}}$ at the center of the mode free band and then broadbanded.

By terminating one end of the window and step with a non-reflective load as shown in schematical FIG. 7, the Smith plot admittance function of the window was determined in the conventional way with slotted line as measured from an arbitrary but known plane, see FIG. 7, over the frequency range of interest to obtain the desired impedance plot $Z_I$ as shown in FIG. 5 by variation of the distance d', see FIG. 7, of the window to the E-plane discontinuity. A desired shape is obtained when the impedance function $Z_I$ for a given $d'$ could be easily moved to circle the origin by the addition of another E-plane discontinuity on the opposite side of the block. The $Z_I$ function is appropriately shaped when $f_0$ (the center frequency of the passband) lies on or near the origin of the Smith plot and the bandedges of the passband are approximately symmetrical about either reactive branch of the circle on the Smith plot where the resistance or conductance is unity.

The point at which this admittance circle or loop goes through the origin of the Smith plot is the frequency at which the window is resonant, or a half-wavelength long, the impedance plot $Z_I$ is enlarged (more points are near the center) and thus broadbanded due to the compensation of the first E-plane step.

Now it is seen that a properly chosen reference at plane X on the Smith Chart and as shown in FIG. 7 would move the greater part of the admittance circle into a path concentric with a point which later can be moved to the origin of the Smith plot. Indeed, as we move to within $.7\lambda_g$ from the window the curve labeled as $Z_{II}$ results. Naturally the impedance loop or plot $Z_{II}$ has opened up because of the different rate of change between high and low frequency points when they are referenced on a normalized Smith plot. The function (circle or loop) can now be brought down and to the right to circle the origin by the addition of an appropriate step at this point. The reason for this shift of loop $Z_{II}$ to circle the origin is due to the change in impedance of the step and the additional effect of the capacitive reactance of this step; in fact, plane X was chosen so that suitable compensation could be made there.

After an appropriate step is made at plane X the function is shifted as seen to plot $Z_{III}$. All points are equal distance from the origin indicating a constant V.S.W.R. for a band of frequencies. A further slight improvement of the match can now be made.

Since impedance points of constant V.S.W.R. may be closed by moving toward the load (on the Smith plot high frequency points move faster than low frequency points because of smaller $\lambda_g$), it is excepted that the admittance circle points around the origin can be found to cluster at some reasonable distance from the window. Since a filter network was anticipated in the beginning, this admittance cluster would again be expected. A position was sought such that the cluster would fall on the purely positive imaginary susceptance ordinate. This is found to occur $.2\lambda_g$ from the window on the air side as was described previously. Obviously the above technique is applicable to a plurality of sets of differential impedance values at $Z_I$, $Z_{II}$, $Z_{III}$ with a block type of window disposed in the center waveguide section. The important point is that a pair of E-plane impedance discontinuities can be

utilized (to broadband a block window) while simultaneously providing impedance matching between differential impedance sections in order to obtain excellent substantially reflectionless electromagnetic energy transmission through the coupler. Trimmer inductive irises **17, 18** are advantageously positioned in the coupler to optimize the final match.

It is to be understood that the aforementioned design approach is equally applicable to any given set of load and source impedance values as well as being applicable to circular guides and windows.

Examination of FIG. 4 shows that for the parameters set forth in FIG. 3, a V.S.W.R. of less than 1.15 was achieved in the band from 2.89 kmc. to 3.28 kmc.

FIGS. 9, 10 and 11 depict variants of the coupler depicted in FIGS. 1, 2, 3 and 6 wherein more complex mechanical arrangements are depicted for providing a pair of E-plane discontinuities on either side of a block window. The embodiment of FIGS. 1, 2, 3 and 6 is obviously superior from a design standpoint since it is extremely simple to fabricate and thus economical, and also capable of handling higher powers without arcing due to the presence of only one rounded edge at the E-plane discontinuities.

FIG. 9 depicts a coupler **42** having a pair of E-plane discontinuities **30, 31** lying in a single plane on the one side of the block windows **32** and a single E-plane discontinuity **33** on the opposite side.

FIG. 10 depicts a coupler having a pair of **34, 35** of E-plane discontinuities lying in a single plane on the one side of block window **36** and another pair **37, 38** of E-plane discontinuities lying in a single plane on the opposite side of the window **36.**

FIG. 11 depicts a coupler **44** having an E-plane discontinuity **39** on the one side of block window **40** and an E-plane discontinuity **41** on the opposite side of the window with the E-plane discontinuities being on opposite broadwalls of the coupler.

In each of the above coupler designs depicted in FIGS. 9–11 the design techniques set forth previously are advantageously employed to broadband the window and provide impedance matching characteristics for the differential impedance conditions. Quite obviously differential impedance conditions beyond the source and load points (input and output portions of the coupler) may be prohibitively large in value such that adequate broadbanding and matching is unobtainable with just a single E-plane discontinuity on each side of the window as in the preferred embodiment or with the embodiments of FIGS. 9–11.

The present invention encompasses couplers with block windows and E-plane discontinuities having known impedance matching techniques utilized prior to the source and load points of the coupler in order to bring the differential impedance levels within the limits of the broadbanding and matching properties of a pair of E-plane discontinuities disposed on either side of a block window.

Furthermore, if ghost modes do not present a problem the present invention obviously is applicable to broadbanding a block window regardless of the rationale which is used to determine the width and height dimensions thereof. The aforementioned design techniques are obviously extendible to encompass coupler designs such as depicted in the several embodiments of the present invention which have less than optimized bandwidths by selecting appropriate $Z_I$ and $Z_{II}$ plots in order to obtain a predetermined $Z_{III}$ plot which is more or less governed by the source requirements as mentioned previously. The 180° space rotated embodiments depicted in FIGS. 9–11 are obviously applicable to circular guides as well as rectangular.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

**1.** A high frequency electron discharge device including electron beam forming and projecting means, means for providing electromagnetic interaction between electromagnetic energy and an electron beam and electromagnetic transmission coupler means coupled to said electron discharge device, said coupler means including a hollow waveguide having a low loss wave permeable block window disposed therein in vacuum sealed relationship, the hollow waveguide portion of said coupler having an E-plane impedance discontinuity disposed on each side of said block window, said coupler being further characterized by having waveguide portions on the outwardly directed ends of said E-plane impedance discontinuities, said E-plane impedance discontinuities being spaced from said block window such that said block window is broadbanded, said block window having a length as measured along the transmission path of said coupler which falls within the following range; substantially $n/2\lambda_{g\epsilon}$ where $\lambda_{g\epsilon}$ is determined at the center frequency of the passband of the coupler and $n$ is any positive integer, said waveguide portions on the outwardly directed ends of said E-plane impedance discontinuities having differential impedance values, said E-plane impedance discontinuities being inter-related with said block window such as to simultaneously broadband said coupler passband while providing a substantially reflectionless impedance transformation between said differential impedance values for electromagnetic energy within said coupler passband.

**2.** The device as defined in claim **1** wherein said block window has a length as measured along the transmission path of the coupler which is approximately equal to $n/2\lambda_{g\epsilon}$ where $\lambda_{g\epsilon}$ is determined at the center frequency of the passband of the coupler and $n$ is any positive integer.

**3.** The device as defined in claim **1** wherein said E-plane impedance discontinuities are further characterized by their abrupt occurrence at two spaced transverse planes through said hollow waveguide.

**4.** The device as defined in claim **1** wherein said E-plane impedance discontinuities are restricted to a single side of said hollow waveguide.

**5.** The device as defined in claim **1** wherein said block window and said hollow waveguide are rectangular.

**6.** The device as defined in claim **1** including an inductive iris disposed in spaced relationship from one of said E-plane impedance discontinuities.

**7.** The device as defined in claim **1** wherein said E-plane impedance discontinuities are positioned on at least two 180° space-rotated portions of said hollow waveguide is spaced transverse planes through said hollow waveguide to thereby form pairs of E-plane impedance discontinuities.

**8.** The device as defined in claim **1** wherein one of said E-plane impedance discontinuities is positioned on at least two 180° space rotated portions of said hollow waveguide in a transverse plane through said hollow waveguide to thereby form a pair of E-plane impedance discontinuities.

**9.** The device as defined in claim **1** wherein said E-plane impedance discontinuities are positioned on 180° space rotated portions of said hollow waveguide.

**10.** A high frequency electromagnetic coupler comprising a hollow rectangular waveguide having a low loss wave permeable block window disposed therein in vacuum sealed relationship, said block window having a length as measured along the transmission path of said coupler which falls within the following range; substantially $n/2\lambda_{g\epsilon}$ where $\lambda_{g\epsilon}$ is determined at the center frequency of the passband of the coupler and $n$ is any positive integer, said hollow waveguide portion of said coupler having an E-plane impedance discontinuity disposed on each

side of said block window, said coupler being further characterized by having waveguide portions on the outwardly directed ends of said E-plane impedance discontinuities, said impedance discontinuities being spaced from said block window such that said block window is broadbanded.

**11.** The coupler as defined in claim **10** wherein said E-plane impedance discontinuities are further characterized by their abrupt occurrence at two spaced transverse planes through said hollow rectangular waveguide.

**12.** The coupler as defined in claim **10** wherein said E-plane impedance discontinuities are restricted to a single side of said hollow rectangular waveguide.

**13.** The coupler as defined in claim **10** including an inductive iris disposed in spaced relationship from one of said E-plane impedance discontinuities.

**14.** The coupler as defined in claim **10** wherein said E-plane impedance discontinuities are positioned on at least two 180° space rotated portions of said hollow rectangular waveguide in spaced transverse planes through said hollow rectangular waveguide to thereby form pairs of E-plane impedance discontinuities.

**15.** The coupler as defined in claim **10** wherein one of said E-plane impedance discontinuities is positioned on at least two 180° space rotated portions of said hollow rectangular waveguide in a transverse plane through said



hollow rectangular waveguide to thereby form a pair of E-plane impedance discontinuities.

**16.** The device as defined in claim **10** wherein said E-plane impedance discontinuities are positioned on 180° space rotated portions of said hollow rectangular waveguide.

**17.** The device as defined in claim **10** wherein said waveguide portions on the outwardly directed ends of said E-plane impedance discontinuities are characterized by having differential impedance values.


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