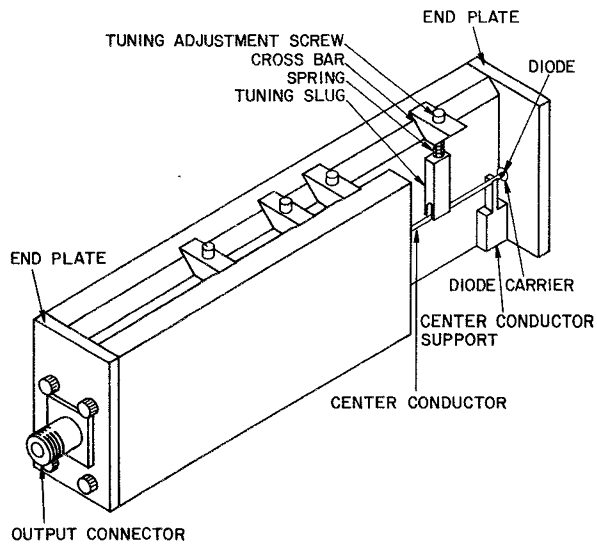

Fig. 1. Parallel plate TRAPATT circuit.

A Circuit for Rapid Evaluation of TRAPATT Diodes

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Abstract—**A parallel plate transmission line circuit has been developed which facilitates rapid testing of experimental TRAPATT diodes. In this circuit the impedance of each tuning element can be continuously varied. This is an appreciable advantage over conventional coaxial TRAPATT circuits which use fixed diameter slugs.**

I. INTRODUCTION

TRAPATT diodes are semiconductor devices which generate microwave power in the 0.5–12-GHz range. Since the power output and efficiency of these devices are dependent upon providing a suitable impedance match at each of several harmonically related frequencies, it is beneficial to have optimum flexibility in adjusting impedances, particularly for the evaluation of devices of different areas and for series and/or parallel combinations of devices. To this end, a new parallel plate transmission line test circuit was developed which allows continuous variation of the impedance of the tuning elements used to produce TRAPATT operation. The length of the tuning elements can also be quickly changed simply by removing undesired tuning elements through a slot in the top of the circuit and substituting their replacements.

II. CONVENTIONAL CIRCUIT

The most common type of TRAPATT test circuit is a 50-Ω coaxial line which contains movable metallic or dielectric sleeves which are equivalent to short sections of low impedance transmission line [1]. Typically, four sleeves are used as a compromise between maximizing versatility and minimizing complexity. Tuning is accomplished by changing the position of the sleeves relative to the diode. The tuning flexibility of this circuit is limited because the length and characteristic impedance of a sleeve is fixed, and it is only by disassembling the circuit that a sleeve can be changed. Since disassembly alters the tuning adjustment of the other sleeves, it is necessary to readjust all of the tuning elements whenever a sleeve is changed. In this letter a circuit is described which overcomes this limitation, and has several other advantages as well.

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III. PARALLEL PLATE CIRCUIT

A cutaway drawing of the circuit is shown in Fig. 1. A cylindrical conductor rigidly mounted between two parallel ground planes forms a section of parallel plate transmission line with a characteristic impedance of 50 Ω. The dimensions of the parallel plate transmission line were chosen so that the diameter of the center conductor is the same as that of 7-mm 50-Ω coaxial air line. Plates at each end of the circuit hold the ground planes parallel and provide mounting for the diode and output connector at opposite ends. The packaged TRAPATT is mounted on a carrier which screws into a threaded hole at the diode end of the circuit so that diodes can be interchanged without disturbing the rest of the circuit. The transition between the parallel plate transmission line and 50-Ω coaxial line at the output end of the circuit is provided by a modified type N connector mounted on the plate.

Tuning is accomplished by moving rectangular slugs, 3/16–3/8 in long, which make a sliding electrical contact to the parallel ground planes and are insulated from the center conductor. These slugs are supported by a crossbar at the top of the circuit with a spring loaded adjustment screw connecting the crossbar and the slug. Turning the screw changes the distance between the slug and the center conductor. The depth of penetration of the tuning slug determines the magnitude of the impedance presented to the diode while the distance between the slug and the diode determines the phase of the impedance. The bottom of the slug is cut to fit closely around the center conductor, allowing lower impedances to be attained than would be possible with a flat bottomed slug. Spring loading the slug support screw decreases backlash when the slug penetration is adjusted, and makes the slug and crossbar a more rigid unit which facilitates lateral movement of the slugs in the transmission line.

The coaxial and parallel plate circuits were compared by testing identical diodes in both circuits. Diodes which gave poor performance in the coaxial circuit gave better performance in the parallel plate circuit. For example, every sample tested from one particular wafer burned out in the coaxial circuit during tuning before showing any evidence of TRAPATT oscillation. On the other hand, samples from the same wafer tested in the parallel plate circuit gave 3–7-W output at 2.5 GHz with efficiencies of 9–17 percent. Typical device results from yet another wafer are shown in Table I. In general, the performance improvement for a device in the parallel plate circuit is less marked if the device operates with high efficiency in the coaxial circuit. Test 1 was run in a coaxial circuit with two $\frac{1}{4}$-in and two $\frac{3}{8}$-in sleeves, each of 10-Ω impedance with the short sleeves closest to the diode. Test 2 was run in the same circuit, but the positions of the long and short sleeves were interchanged. Test 3 was run in the parallel plate circuit with two 3/16-in slugs and three 3/8-in slugs.

TABLE I
Comparison of Results from NRL TRAPATT in Coaxial and Parallel Plate Circuits

Test No.	Power Out	Bias Voltage	Bias Current	Eff.	First Sleeve	Circuit
1	7.6w	38v	.88a	23%	short	coaxial
2	8.7w	47v	.60a	31%	long	coaxial
3	10w	48v	.64a	32%	long	parallel plate

The results in Table I show that the order of the slugs makes a difference. Changing from the conditions of test 1 to test 2 required disassembling the coaxial circuit. In the parallel plate circuit used in test 3, the slugs were quickly rearranged, as was necessary to maximize output power, without disassembly of the circuit.

For most devices tested in the parallel plate circuit, it was found convenient to start with 3 slugs and adjust them for best diode performance. Then, additional slugs were added if necessary to maximize power output and pulse quality. Since the slugs are easily inserted and removed, this process is accomplished much more rapidly than the equivalent process with the coaxial circuit.

In addition, the open slot allows observation of the diode and center conductor. This is particularly useful when trying to establish electrical contact with a diode unprotected by a package as is the case for some experimental configurations. Moreover, the parallel plate circuit allows the convenient insertion of probes into the circuit for sampling the RF energy in the vicinity of the diode.

IV. CONCLUSIONS

A new circuit has been developed which has the following advantages over the conventional coaxial circuit.

1) The new design permits continuous adjustment of the slug penetration, and thus, continuous adjustment of the impedance of the slug.

2) Slugs can be easily removed and inserted without disturbing adjacent slugs.

ACKNOWLEDGMENT

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Transmission Line Impedance Matching Using the Smith Chart

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***Abstract*—A graphical computation method is described for transforming complex load impedances into resistive load impedances using transmission line matching sections. The Smith chart is used even though the characteristic impedance normalizing factor is unknown.**

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Paraphrasing Smith [1], physical laws can usually be represented either graphically or mathematically. The graphical construction for the Smith chart which follows has a fairly simple mathematical counterpart. It is of interest, however, because it makes use of the chart even though the characteristic impedance normalizing factor is one of the unknowns of the problem. It thus represents a small but unique addition to the many uses of an already useful tool.

The problem being considered is that of finding the characteristic impedance Z_0 and electrical length l/λ of the transmission line which transforms a given load impedance Z_L into some other impedance Z_S. This is usually done to provide a conjugate match to a source, a resistive load for a transmission line, etc. The quarter-wave transformer (or quarter-wave optical coating) are familiar examples of the special case where the source and load impedances are purely real. Here we consider the somewhat special case of transforming a complex load impedance into a real source impedance. For this case, Jasik [2] gives the equations for Z_0 and l/λ (λ = wavelength in the transmission line) as

$$Z_0 = \left(R_S R_L + \frac{R_S X_L^2}{R_L - R_S}\right)^{1/2} \tag{1}$$

and

$$l/\lambda = \frac{1}{2\pi}\tan^{-1}\frac{Z_0(R_S - R_L)}{R_S X_L}. \tag{2}$$

Here $Z_S = R_S + j0$ and $Z_L = R_L + jX_L$. This problem can be constructed on the Smith chart as illustrated in an example to follow (Fig. 1).

We consider the example of matching $Z_L = K(1 - j2)$ into $Z_S = 1/3K + j0$. Since we do not know Z_0 we cannot plot Z_L as a point on the chart. We can, however, plot the locus of all impedances whose real component is one half of their imaginary one, with a negative imaginary part. The arc A–A' is this locus[1] and the continuation of this arc would form a circle centered at 0. The line 0–Z_0 has length (Re Z_L/Im Z_L)R where R is the radius of the chart being used. The normalized load impedance $Z_L' = Z_L/Z_0$ must lie on the arc A–A' while the normalized resistive input impedance $Z_S' = Z_S/Z_0$ must lie on the line A–A'. We are thus looking for a pair of points, one on arc A–A', one on the line A–A', with the proper transformation ratio on the real parts (in this case 1/3). Further, this pair of points must lie on a circle about $Z_0' = Z_0/Z_0 = 1$, the center of the chart, because all impedance levels in a transmission line lie on such a circle on the Smith chart. Detecting such a pair of points requires a trial and error search procedure. However, this search is made easier by the fact that lines connecting pairs of points with the proper transformation ratio on the real part will all converge at the point P on the circle centered at 0. The point P can be detected by connecting one or two arbitrary pairs of such points with lines such as P–B and P–C. Once the point P is located, it is relatively easy to place a straightedge through P at various angles and measure the distances from Z_0' to the intersections of the straightedge with the arc A–A' and line A–A' until the angle is found which equalizes these distances. In this case, the solution is the line P–Z_S'–Z_L'. One then knows (from the Smith chart coordinates of Z_S' and Z_L') that $Z_S/Z_0 = 0.22$ or $Z_0 = 4.55Z_S$ and $l/\lambda = 0.159$. Since $Z_S = 1/3K$, $Z_0 = 1.52K$. Equation (1) yields $Z_0 = 1.53K$,

[1] It has been pointed out to the author by E. J. Drazy that these arcs are the arcs of constant impedance angle on the polar form of the Smith chart.