Microwave News

DEVELOPMENTS IN MICROWAVE TUBES AND DEVICES

Number 6

"ACCUTUNE" THE MULTI-FUNCTION MAGNETRON

Radar echoes can be degraded by background echoes (clutter), by electronic countermeasures (e.c.m.) and by the changing aspect of an irregular target causing glint. A very good technique for obtaining a clear radar picture is "frequency agility", which is a rapid variation of the radar beam frequency. When this technique is used, the random effects due to clutter, added together over a short period of time, cancel one another out, making the target more conspicuous; e.c.m. become ineffective since it is difficult for a jamming system to lock onto and follow a random frequency variation. Glint is minimised because the reflection characteristics of complex targets are frequency sensitive, so where the target shape presents an unfavourable aspect at one frequency it will give a strong echo at another frequency.

Modern radar systems thus require frequency agility. But the ability to tune frequency quickly is of little interest in itself, the radar receiver must also be tuned to match each pulse. So the accuracy of frequency prediction becomes a vital parameter.

Equally important, of course, is the inherent stability of the magnetron itself particularly its ability to maintain frequency despite changes in load and temperature, because these changes would not be indicated by the frequency read out. The superior performance and stability of the coaxial magnetron make this the obvious choice for frequency agile systems. The coaxial magnetron has greater freedom from unwanted electronic tuning (pushing) by a factor of 5:1 over a conventional magnetron, and greater freedom from load reactance (pulling) by a factor of 3:1 over a conventional magnetron.

Another advantage of the coaxial magnetron is its clean spectrum. The coaxial magnetron sidebands are suppressed and both spurious outputs and harmonics are low. This has become important for avoiding mutual radar interference and in complying with new radiation standards.

Present day requirements call for many functions previously dealt with by separate radar systems to be combined into one multipurpose radar. Thus doppler and moving target indicator (m.t.i.) modes often have to be available in addition to pulse to pulse agility. The "Accutune" coaxial magnetron has proved itself an ideal tube for multi-function radar systems. It changes frequency quickly, typically by 400 MHz in X-band within 50 m.sec; and the frequencies transmitted can be predicted accurately, within 0.5 MHz in X-band. Furthermore the Accutune magnetron is capable of even more precise tuning when connected to an accurate control system, such as the discriminator output of a "stalo".

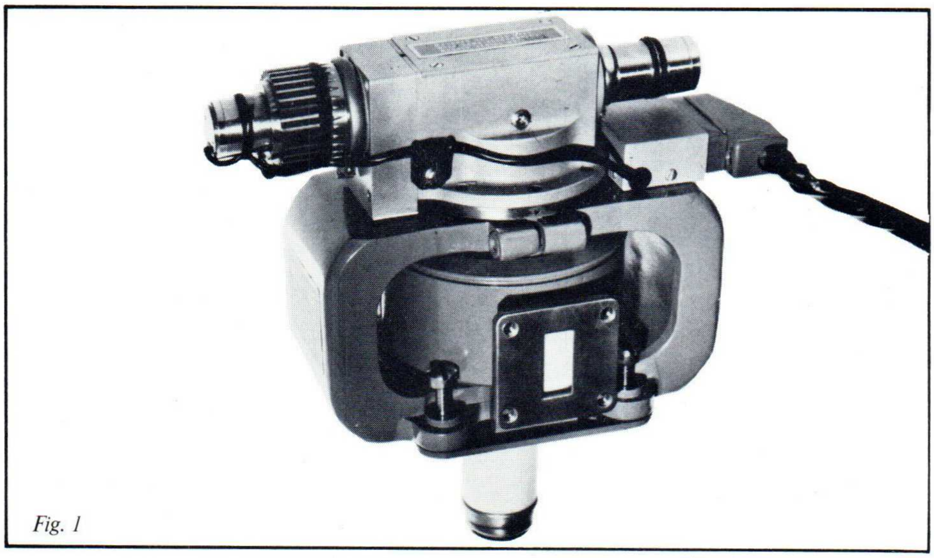

Fig. 1

In service, the accutune magnetron has been shown to be stable, to withstand vibration and shock and to have a long life. Furthermore all alignment and calibration takes place within the tuner itself, which is a separate unit, and can be changed in the field just by loosening a few screws, without requiring a sophisticated test set. The temperature coefficient can be as low as 0.1 MHz/°C.

The tuner is geared to a servo motor, and the frequency readout is a frequency-voltage analogue A servo comparator amplifier, the VZW-1010 is used to compare the voltage command and the voltage readout. Should a difference occur, the error signal is amplified and used to drive the servo motor rapidly to the desired frequency.

Some examples of the capability of the Accutune magnetron are shown in figures 2, 3, 4 and 5 overleaf. In order to obtain clear pictures of the frequency changes, only periodic input signals are shown, but the tuner mechanism will follow any wave form, including completely random waveshapes. The Accutune magnetron offers system designers an unparalleled latitude in the optimisation of the multi-function radar parameters. Mode selection merely requires changing one electrical signal, and is as simple

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microwave 73

The versatility of "Accutune" magnetrons is being demonstrated on the EMI-Varian stand at the Microwave '73 exhibition at Brighton, England, from 19th-21st June 1973. Also prominently featured on the stand is a model of the PT1030, a pulsed L-band klystron giving a peak output of 5 MW, and having a 3 dB bandwidth of 12%. Other state-of-the-art devices include high power crossed field amplifiers, travelling wave tube amplifiers, and the world's only electrostatically focussed klystron in large scale production, the PT 1010.

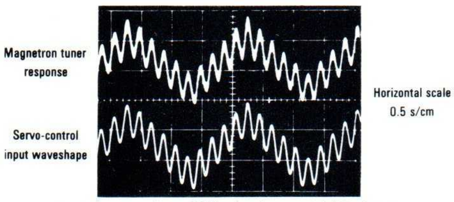
The wide range of products on view include reflex klystrons, coaxial magnetrons, microwave diodes, power grid tubes, printed microwave aerials and radar front ends. There are also working demonstrations of complete microstrip and millimetric systems.

(continued from Page 1)
as changing stations on a push button radio.

Many radar systems in operation now can be upgraded for frequency agility and m.t.i. economically by retrofitting Accutune magnetrons, and can then have a much extended effective lifetime. In the vast majority of systems one can replace the existing system magnetron with an Accutune coaxial magnetron with no change to the modulator/transmitter unit.

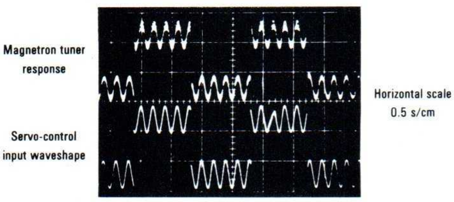
The one area that usually requires change is the automatic frequency control receiver (a.f.c.) and the local oscillator circuitry. In applications where it is intended that transmitter frequency changes should occur only on an antenna scan to scan basis, the existing system a.f.c. will usually be adequate. However, where operation with pulse-to-pulse frequency agility is intended, one must have an electrically tunable local oscillator and a.f.c. circuitry which can complete its function within the time of the transmitted pulse. These units are always custom designed because no two radars require exactly the same performance of the receiver.

EMI-Varian offer a range of alternatives from merely supplying the frequency agile hardware, to undertaking the complete system retrofit. The range of Accutune magnetrons available is outlined in the table.



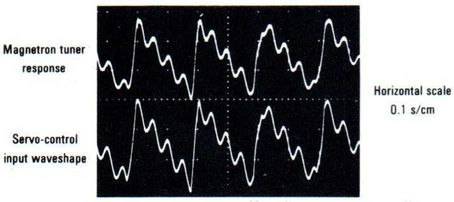
Control input waveshape: 0.5 Hz triangular wave + 5.0 Hz sine wave

Fig.2



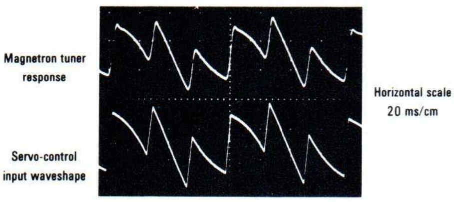
Control input waveshape: 0.5 Hz square wave + 5 Hz sine wave

Fig.3



Control input waveshape: 5 Hz ramp + 20 Hz sine wave
Total frequency excursion: 300 MHz (X-Band)

Fig.4



Control input waveshape: 15 Hz ramp + 5 Hz sine wave
Total frequency excursion: 150 MHz

Fig.5

ACCUTUNE MAGNETRONS

Operating Frequency (GHz)	Minimum Peak Output (kW)	Tuning Range (MHz)	Cycling Rate (Hz)	Maximum Pulse Duration (us)	Maximum Duty Cycle	Maximum Pulling Factor (MHz)	Maximum Pushing Factor (MHz/A)	Nominal Temperature Coefficiency (MHz/A°C)	Type Number
8.54-9.60	200	75	75	2.8	0.001	5	0.1	0.2	SFD-354A
8.54-9.60	200	75	75	2.8	0.001	5	0.1	0.2	SFD-367
8.6-9.6	250	60	95	2.5	0.001	5	0.1	0.2	SFD-360
9.1-9.5	75	75	75	4.0	0.001	6	0.1	0.2	SFD-380A
9.10-9.65	60	30	200	3.5	0.0011	6	0.1	0.2	SFD-363
9.25	75	150	100	4.0	0.001	6	0.1	-0.2	SFD-380F
9.25	200	500	25	2.8	0.001	5	0.1	-0.05	VMX-1003
9.25	200	250	30	2.8	0.001	5	0.1	-0.05	VMX-1004
16.0-17.0	35	30	200	2.0	0.0008	8	0.1	0.4	BLM-178
16.0-17.0	60	30	200	3.5	0.0012	8	0.1	0.4	BLM-181
16.5	65	200	150	2.2	0.0011	8	0.15	0.4	VMU-1048
16.8	35	400	150	1.0	0.001	15	0.25	-	SFD-345
34.0-35.0	45	300	150	1.0	0.001	10	0.5	0.4	VMA-1043

Fig.6

EMI-Varian and Troposcatter Communications

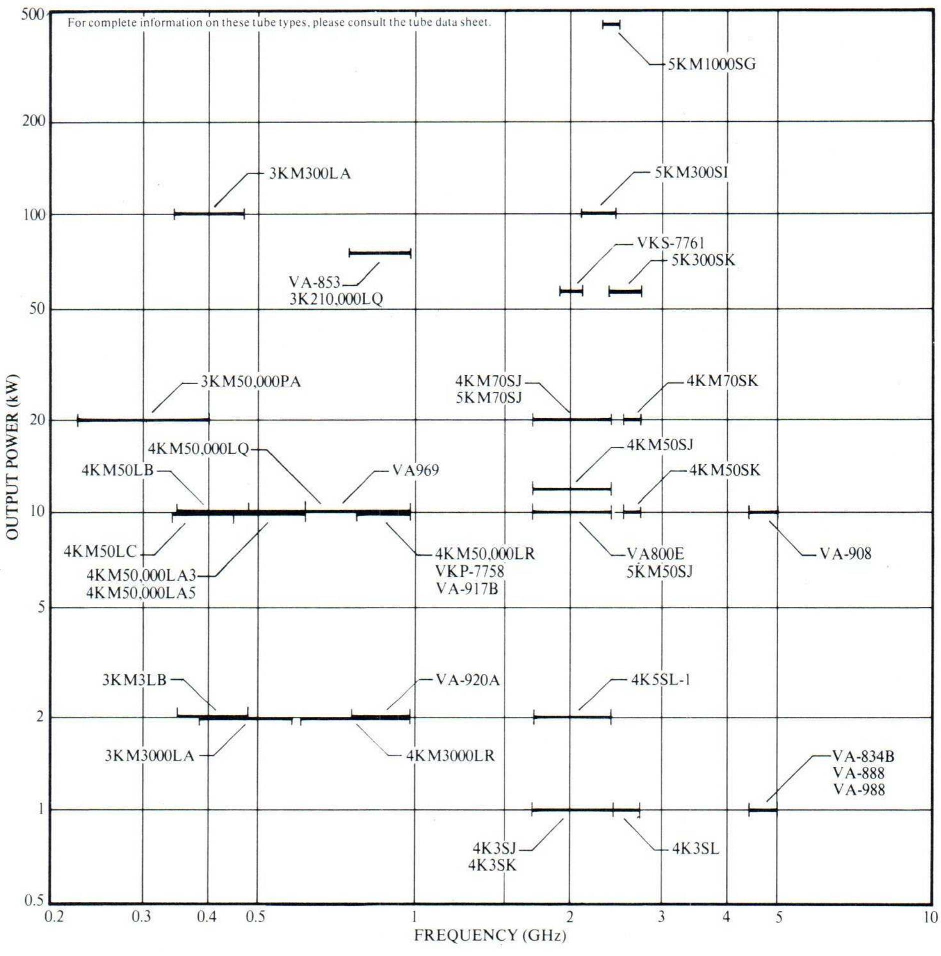
Tropospheric scatter, or just simply "tropo" communication is a method of bouncing microwaves in the u.h.f. and s.h.f. bands off the troposphere to effect radio communications between points on the earth's surface separated by moderate distances of between 70 and 600 miles. By operating some spans in tandem, communications may be extended over many thousands of miles with excellent reliability and information capacity.

Troposcatter systems utilise high power and large directional antennae, and provide a means of radio communications over distances not covered either by short range u.h.f. and s.h.f. line-of-sight systems or by h.f. and long range l.f. systems.

Firmly established in the bulk of tropo systems in use today is the klystron, and numerous such tubes have been developed between 200 MHz and 5 GHz, with powers of up to 500 kW (c.w.).

Representative types of these tubes available from EMI-Varian are shown in the chart below.

CHART OF C.W. POWER KLYSTRONS FOR TROPOSCATTER APPLICATIONS



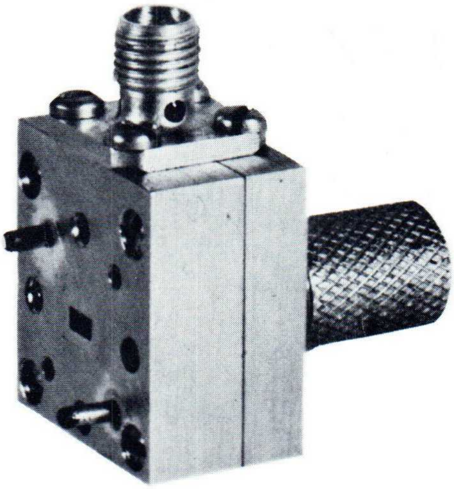
Certified Power

EMI-Varian thermistor heads come complete with individual calibration certificates. The head consists of a waveguide mount containing a tunable short circuit, and a plug-in waveguide wafer in which the thermistor is mounted. Fixed tuned models are also available to special order.

The bandwidth of the fixed tuned models is typically 10% of the nominal frequency, and this is also the instantaneous bandwidth of the tunable versions.

Spare thermistor wafer and head assemblies are available, unmounted. The heads can also be supplied in WG23 to special order.

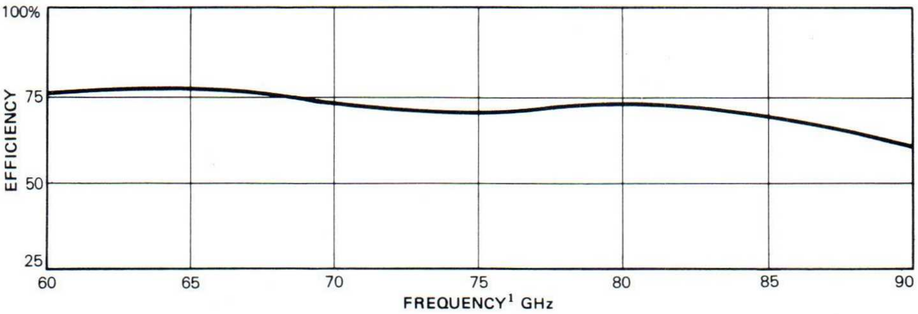
These thermistor heads cover the frequency range 20-110 GHz.



THERMISTOR HEADS

Model	MMC 12/20	MMC 12/22	MMC 12/24	MMC 12/25	MMC 12/26	MMC 12/27
Tunable frequency range	20–26.5 GHz	26.5–40GHz	40–60 GHz	50–70 GHz	60–90 GHz	75–110 GHz
	Min. Typ. Max.	Min. Typ. Max.	Min. Typ. Max.	Min. Typ. Max.	Min. Typ. Max.	Min. Typ. Max.
Power handling mW	14	14	14	14	14	14
Minimum Efficiency within band %	60 70	60 70	50 60	50 60	50 60	40 50
R.F. v.s.w.r.[1] —:1	2 3	2 3	2 3	2 3	2 3	2 3
Resistance ohms	200	200	200	200	200	200
Temperature coefficient	negative	negative	negative	negative	negative	negative

Typical Efficiency Curve for MMC 12/26 (Optimising at each Frequency)



Cumulative Subject Index

In response to many enquiries we publish an index of the subjects covered in Microwave News, issues 1 to 6. In most cases, back numbers are available, free of charge, from our publicity department.

Marconi use EMI-Varian Klystron for North Sea Tropo

Designed for long periods of unattended operation, the new Marconi H3722 troposcatter amplifier has been chosen as the main communications link between British Petroleum's new operations centre at Dyce Scotland and Forte's Field 120 miles out in the North Sea.

The system, the first in Europe to be used on oil production operations, incorporates EMI-Varian's 4K 3SK four cavity 1kW klystron, one of a number of tubes in L-, S-, and C- Bands specifically designed for troposcatter operations.

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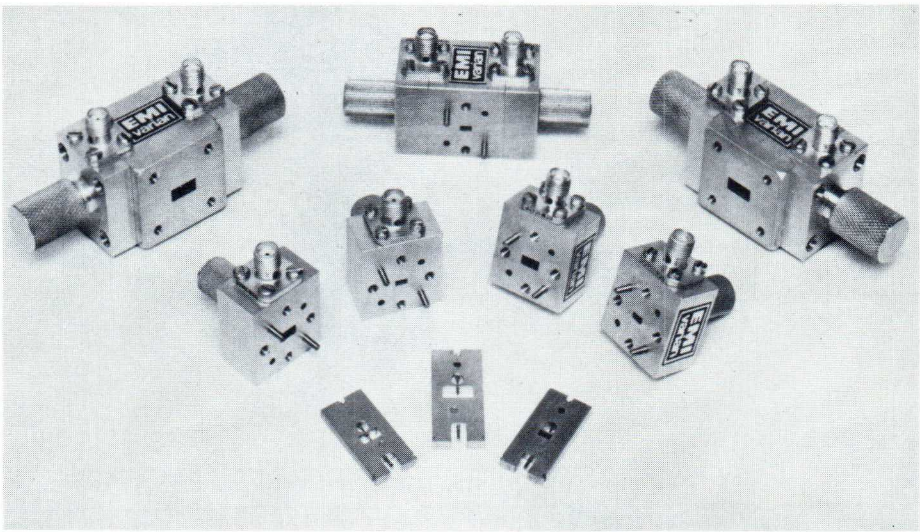
Please send further information on items ticked:-

- ☐ **Accutune Magnetrons**
- ☐ **Millimetric Wavelength Mixers**
- ☐ **Klystrons for Troposcatter Communications**
- ☐ **Gunn effect sources**
- ☐ **Thermistor Heads**

A wide range of technical books, articles, application notes and brochures are available from our Publicity Department.

- ☐ Introduction to pulsed crossed field amplifiers.
- ☐ Effects of system breakdown on crossed field amplifiers.
- ☐ Cooling systems for high power klystrons.
- ☐ Microwave tubes operating hazards.
- ☐ Training manual on power klystron amplifiers.
- ☐ Introduction to coaxial magnetrons.
- ☐ Introduction to dither tuned magnetrons.
- ☐ Rare earth cobalt magnets.
- ☐ Frequency agile magnetron story.
- ☐ The care feeding of power grid tubes (Price £1.75 post free).
- ☐ The coaxial magnetron, its theory and operation in fixed and agile modes (Price £2.50 post free).
- ☐ Back issues Microwave News No......................

Millimetric Wavelength Mixers



The low loss trunk waveguide systems under development in many countries are being designed to operate at gigabit rates with attendant high intermediate frequencies.

The MMC10 series of millimetric mixers has been developed by EMI-Varian Limited for use in such systems and, indeed, any systems with gigahertz intermediate frequencies.

These mixers use a gallium arsenide Schottky barrier diode incorporated in a waveguide wafer. No sliding of this wafer is required for matching, only tuning of the short circuit being necessary. They are available in all waveguide sizes to cover the frequency range 20 GHz to 170 GHz. Extension of the range to 300 GHz is in progress.

The typical conversion loss (including all mismatch losses and mount losses) varies from 4.5 dB at 30 GHz to 11.5 dB at 135 GHz.

Intermediate frequencies up to 14 GHz may be used for devices designed to operate above 40 GHz and up to 8 GHz for those designed to work below 40 GHz.

Excellent broadband mixing is achieved with low v.s.w.r. at both r.f. and i.f. ports.

Both single and balanced versions are available from EMI-Varian. In addition there is a range of single mixers with two r.f. ports for upconverter application, and up to 1 mW may be generated in this mode at frequencies up to 90 GHz.

Test have shown these devices are also sensitive detectors with low flicker noise characteristics (10 dB lower NTR compared with the equivalent point contact devices). The full benefit of these low noise characteristics can be obtained in systems with extremely low intermediate frequencies, such as doppler radars.

Model	MMC 10/20	MMC 10/22	MMC 10/23	MMC 10/24	MMC 10/25	MMC 10/26	MMC 10/27	MMC 10/28	MMC 10/29
Tunable frequency range	20–26.5 GHz	26.5–40 GHz	33–50 GHz	40–60 GHz	50–70 GHz	60–90 GHz	75–110 GHz	90–120 GHz	110–170 GHz
	Min. Typ. Max.	Min. Typ. Max	Min. Typ. Max	Min. Typ. Max.	Min. Typ. Max.	Min. Typ. Max.	Min. Typ. Max.	Min. Typ. Max.	Min. Typ. Max.
Conversion loss[1] dB	5 7	5 7	8 10	8 10	8.5 11	9 11.5	9.5 12	10 13	12 14
I.F. v.s.w.r.[2] -:1	1.1 1.25	1.1 1.25	1.1 1.25	1.1 1.5	1.1 1.5	1.1 1.5	1.1 1.5	1.1 1.5	1.1 1.5
R.F. v.s.w.r. -:1	1.5 2.0	1.5 2.0	1.5 2.0	1.5 2.0	1.5 2.0	1.5 2.0	1.5 2.0	1.5 2.0	1.5 2.0
Power handling mW	30	30	30	30	30	30	25	20	20
Burn-out, peak[3] pulse mW	70	70	70	70	70	70	50	50	40
Tangential[4] Sensitivity dBm	−48	−48	−46	−44.5	−43	−41.5	−40	−37.5	−35
I.F.	10Hz 6GHz	10Hz 8GHz	10Hz 8GHz	10Hz 10GHz	10Hz 12GHz	10Hz 14GHz	10Hz 14GHz	10Hz 14GHz	10Hz 14GHz
Output connector	3mm	3mm	3mm	3mm	3mm	3mm	3mm	3mm	3mm
Flange	UG595	UG599	UG385/U	UG385/u modified	UG387/U modified	UG387/U	UG387/U modified	UG387/U modified	UG387/U modified

Note 1:- Conversion losses:
The quoted conversion losses are checked in each mount as sold, and include all mismatch losses, diode losses and mount losses. For this test the local oscillator input power is set at 1.0 mW and normal a.c. methods are used. It has been found that this method of measurement gives results much nearer to operational measurements than the d.c. incremental method.

Note 2:- Quoted for narrow band operation. For full band coverage the maximum figure is 2:1 when high i.f. is specified.

Note 3:- Pulse length 5 × 10-8ms; duty cycle .001%.

Note 4:- Noise:- The noise characteristic is measured by the tangential sensitivity method, with a post detector bandwidth of 1 MHz, and is typically -43 dBm at 60 GHz. This corresponds to a noise equivalent power of -80 dBm.

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Gunn-effect source: 75mW at 42 GHz.

The VSQ-9035 microwave source is a highly stable, low-noise Gunn effect oscillator which EMI-Varian, Hayes, Middlesex, has introduced for delivering a minimum of 75 milliwatts at 42 GHz.

The new frequency trimmable device permits the design of sensitive parametric amplifiers without bulky, expensive power supplies.

The VSQ-9035 features power stability of less than 0.01 dB/°C and frequency stability of less than 1.0 MHz/°C in any 10°C range from 0°C to 65°C.

The source operates into a 1.3 maximum load v.s.w.r. Nominal input voltage is 12 to 28 V(d.c.) regulated within ± 10%, with 1.2 A(d.c.) maximum input current.

EMI-Varian supplies the complete package with standard sources including the low-noise Gunn effect oscillator, a load isolator, and a voltage regulator.

Models with equally good stability characteristics are available at any frequency between 26.5 and 50.0 GHz.

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Microwave News

DEVELOPMENTS IN MICROWAVE TUBES AND DEVICES

Optimising tube design by Computer

Present day requirements for klystrons and travelling wave tubes are becoming so refined, that it is impossible to meet them without computing assistance with the design. One important factor in the development of modern high performance tubes has been the use of sophisticated simulation techniques which enable alternative designs to be evaluated, and the chosen design to be developed to an advanced stage before the first prototype is built.

The resistance network shown in figure 1 has proved a very useful facility for electron optical simulation. Electrodes are represented by inserting shorting plugs into the network. Where the electrode surface lies between two nodes, pins containing resistors are used to move the simulated electrode the appropriate distance away from the node with the shorting pin.

Electron trajectories are plotted across one mesh square at a time by the EMIAC analogue computer on the right of the photograph. The voltages corresponding to the position and the velocity of the electron as it leaves any particular mesh square are automatically "frozen", whilst banks of uniselectors present the computer with the potentials of the corners of the next appropriate mesh square. The computer controls an X – Y recorder which draws the complete trajectory.

Space charge effects are simulated by feeding currents, scaled to present the charges, into the appropriate mesh points. By re-iteration a consistant result is obtained.

Figure 2 is an example of a plot produced on this equipment. It shows electron trajectories near the output cavity of a ESFK klystron at that time in the r.f. cycle when the field at the cavity gap has a maximum retarding effect on the electrons. It reveals that the slower electrons will enter the cavity and collide with the tuning paddle.

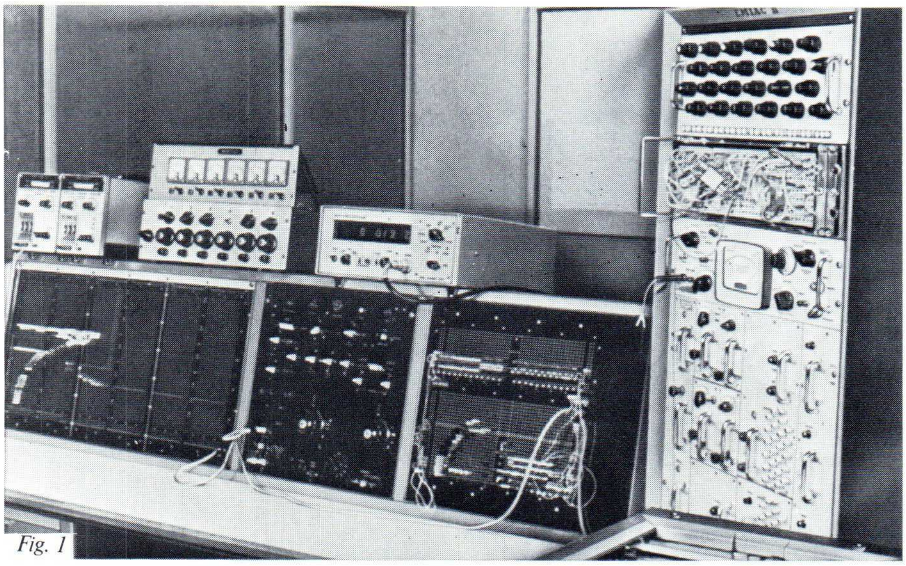

Fig. 1

Digital Methods

The resistance network is a cheap and quick method for obtaining approximate results, on the other hand a digital computer program has greater accuracy and is also more flexible. For example, it can easily be modified to include the option of mixed geometries and to take account of space charge effects automatically. For these reasons a digital computer program is now used for most of our electron optics simulation at high current densities. Digital computer programs are also used for designing microwave windows, predicting small and large signal gains and the phase characteristics, efficiencies and bandwidths of a proposed klystron or travelling wave tube design.

Trajectory Plotting

A program has been written which enables a very simple form of electrode input data to be used. For example, a straight section of an electrode is specified by its end co-ordinates, and a

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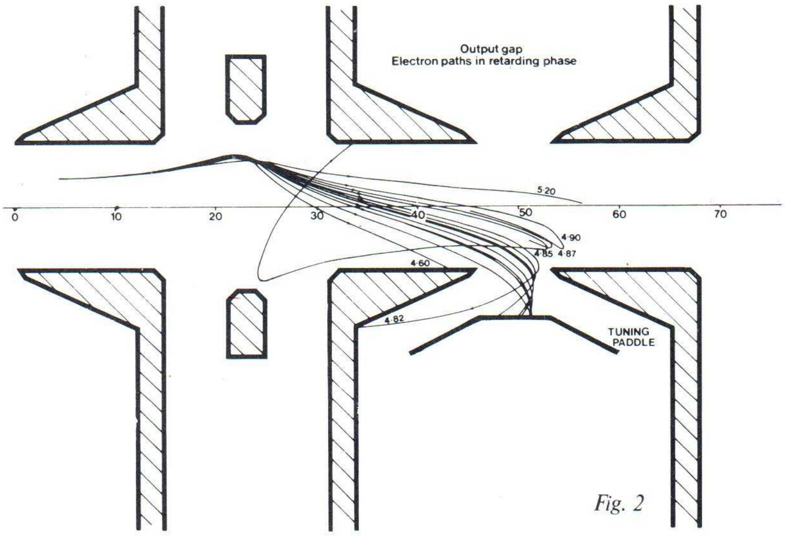


Fig. 2

HELP!

EMI-Varian manufactures and supplies a comprehensive range of microwave tubes, components and solid state devices. To enable system designers and operators to achieve the benefits offered by these devices it is important to be familiar with their operation and necessary precautions and safeguards. A wide range of technical books, articles, application notes and catalogues are available, in most cases free of charge, from our Publicity Department.
See coupon

(continued from page 1)

circular section by the centre and radius of curvature. The region of interest is again divided by a square mesh, and Poisson's equation is solved by a relaxation method to obtain the potential at each anode. The plotting of trajectories and the solution of the Child-Langmuir equation to find the current drawn from each region of the cathode is handled analytically. The program calculates the space charge in the beam and repeats the solution of Poisson's equation and plotting of trajectories several times within each run. The final trajectories are again plotted by an X - Y plotter controlled by the program.

Figure 3 is an example of a plot produced by the digital method. It shows electron trajectories and equipotentials in a typical electron gun for a linear beam tube.

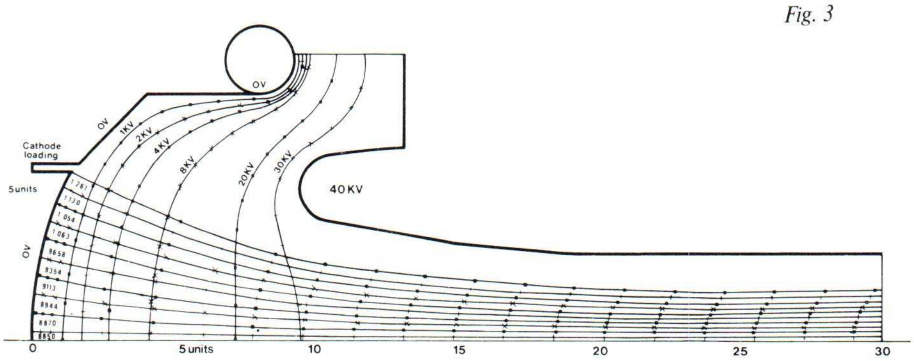


Fig. 3

Microwave Windows

The design of microwave windows is extremely important, particularly with the present trend towards ever broader bandwidth tubes. Badly matched windows can ruin the performance of an otherwise carefully designed tube. EMI-Varian therefore instigated a theoretical study into the design of microwave windows. The outcome was a theory that has proved very effective for designing pillbox, wave guide and co-axial line windows.

The method is to derive the transmission matrixes for the various sections of a window, and hence a transmission matrix for the overall structure. The match of the window is calculated from the coefficients of this matrix. At any one frequency the v.s.w.r. for a variety of values of parameters, such as ceramic thickness and wave

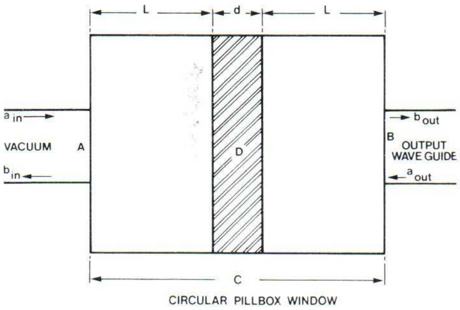


Fig. 4

guide length, is plotted in the form of a map, showing clearly areas of good match. This is repeated for various frequencies throughout the pass-band, and by superimposing the maps one obtains window dimensions that will give a good match over the entire frequency band.

Figure 5 shows computed iso-v.s.w.r. values for differing proportions of the circular pillbox window of figure 4. The shaded area describes a region where the v.s.w.r. is computed to be less than 1.1 for each of the frequencies plotted.

Figure 6 records the measured v.s.w.r. across the same frequency range for two different windows built to these designs.

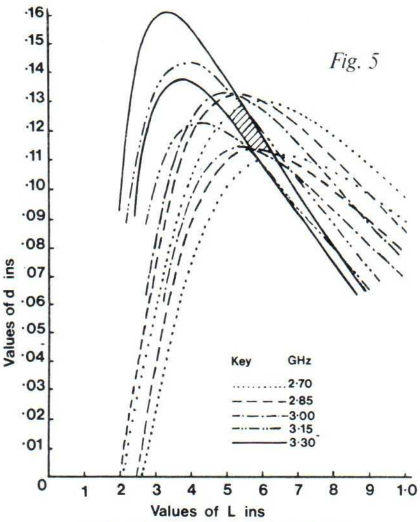


Fig. 5

VALUES OF ISO V.S.W.R; V.S.W.R.=1·10

d \ f	2.70 GHz	2.85 GHz	3.00 GHz	3.15 GHz	3.30 GHz
0.120''	1.09	1.06	1.04	1.06	1.08
0.122''	1.075	1.035	1.05	1.05	1.05

Measured values of v.s.w.r. for a pillbox window with L = 0.550 in., d = 0.120 in. and 0.122 in.

Fig. 6

Small Signal Gain

EMI-Varian has developed a small signal gain theory, which accurately predicts the small signal performance of klystrons, t.w.t.'s or the hybrid tube known as the twystron. The theory represents the electron beam as an infinite series of fast and slow space charge waves which, in the case of tubes having a slow wave structure, interact with the forward and backward waves on the structure, at each cavity.

The complex values (i.e. amplitude and phase) of the forward and backward waves on the structure, and the space charge waves on the beam are assumed to be a vector. This vector is transformed down the tube by a series of matrixes representing the cavity gaps. The theory has been programmed for digital computing and gives a good indication of the gain and bandwidth of a proposed design.

Large Signal Gain and Efficiency

However this small signal analysis is unable to give indications of the efficiency of a proposed design of tube, because the theory used takes no account of the space charge de-bunching effects in the beam. For this reason EMI-Varian uses a large signal theory for a final analysis of their tube design. In this theory the beam is examined as a series of discs of charge.

The beam is injected into the circuit, and the computer calculates the circuit to beam interaction for each disc of charge by solving the equations of motion in the presence of both the circuit and the space charge electric fields, thus obtaining the acceleration on any disc. Integrating the acceleration twice with respect to time, the computer finds the position and hence the phase of any disc. Discs which are accelerated are advanced in phase, and those which are decelerated are retarded in phase. It is thus possible to follow the discs through the circuit, noting the phase changes and the bunching effects which occur. This large signal theory

(continued on page 4)

Rare Earth Cobalt Magnets

Varian Associates has developed a complete facility for manufacturing rare-earth cobalt magnets and has performed extensive testing of rare-earth cobalt materials. Experienced personnel are therefore available to develop and produce magnets to meet your special individual requirements.

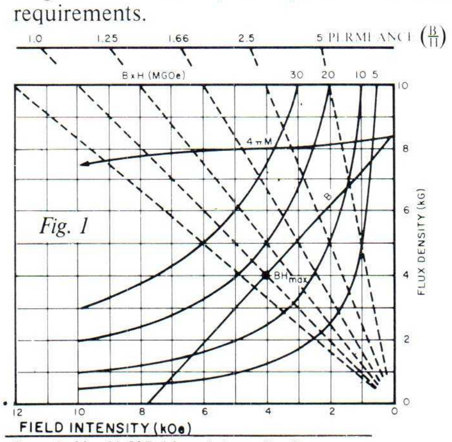


Fig. 1

Sample No. V-537 Material: SmCo
Source: Varian Palce
Shape: TWT Rings Dim: .700 x 1.780 x 1.026
Weight: 17.75 g Vol: 2.09 cm^3 Dens: 8.5 g/cm^3
$_MH_c$ =28,604 Oe, $_BH_c$ =7906 Oe,
B_r =8406 G, $(BH)_m$ =16.2 MGOe,
M_r/M_p = .96, Magnetized in H_p =29.8 kOe

These magnets, which are available through EMI-Varian Ltd., have been manufactured with an energy product in excess of 16 million gauss-oersteds with a residual induction of 8400 gauss and an inductive coercive force of 7700 oersteds. The intrinsic coercive force of the material is over 21,000 oersteds. Figure 1 shows demagnetization and energy product curves measured at the University of Dayton Magnetics Laboratory on production t.w.t. ring magnets. The material is made by a powder metallurgy process which involves sintering to a density of 95% to 100% of theoretical.

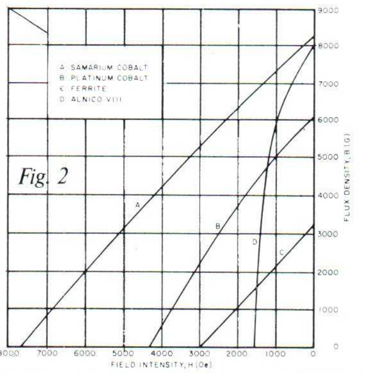


Fig. 2

Looking at the second quadrant performance of typical magnetic materials, as shown in Figure 2. we see that the rare-earth cobalt materials, such as samarium cobalt, offer substantially higher field strengths than conventional materials.

The thermal stability of the material has been thoroughly investigated. Using magnets made for t.w.t. ppm focussing, that operate on very low load lines, innumerable tests with long exposures at elevated temperatures yielded the following results: at 200°C, the irreversible loss of magnetization averaged 3% and, at 250°C, the loss was only 8%. Recent investigations show close control of particle size and particle size distribution, as well as the sintering process, greatly improve high temperature stability.

Another aspect of temperature to be considered is the reversible temperature performance. Samarium cobalt, as presently manufactured, exhibits an inherent temperature coefficient of 0.04%°C. For applications requiring smaller field variations with temperature, standard temperature compensation techniques, such as those used with ferrite magnets, are appropriate.

Varian's rare-earth cobalt magnets can be stabilized for operation at temperatures from room temperature to 300°C. As long as the magnets operate below the temperature at which they are stabilized, the thermal effects are reversible and are a function of the thermal coefficient.

The maximum energy product of the magnets decreases with increasing temperature as indicated by the curves of Figure 3.

Caution is required when attempting to change the energy levels of rare-earth cobalt magnets. After being temperature stabilized, they can be weakened, but cannot be remagnetized to higher energy levels without being temperature stabilized again.

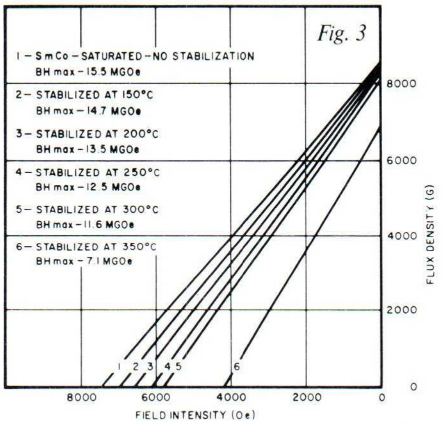
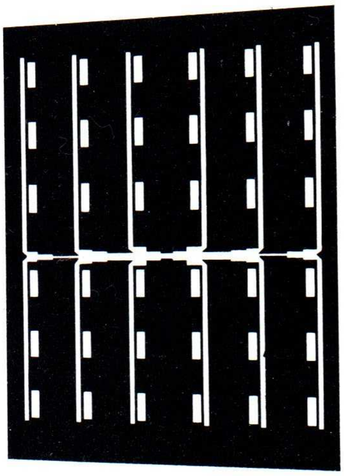


Fig. 3

Material	Maximum Energy Product Range (MGOe)	Reversible Temperature Coefficient % °C
Alnico 5	4.0 - 5.0	0.025
Alnico 8	6.0 - 8.0	0.025
Pt Co	7.0 - 9.0	0.015
Barium Ferrite	2.0 - 3.0	0.19
Samarium Cobalt	14.0 -20.0	0.04



Printed Microwave Aerials 1–40 GHz

EMI-Varian printed microwave aerials offer considerable savings in size and weight over more conventional aerials. Furthermore a centre feed design is possible, so that the beam axis can be normal to the aerial for all frequencies. However, the aerial can also be designed to give a beam at any angle up to 45° from the normal.

Any combination of E & H beamwidths is possible within the range 4° to 90°, in either plane. The trade-off between aerial gain and beamwidth is shown in the following examples.

3db beamwidth	4°x4°	10°x4.5°	20°x4.5°	12°x15°	30°x90°
Aerial gain (dB)	30	26	23.5	21.5	9
X-band aerial Weight (kg)	1.35	0.48	0.24	0.13	0.10

Bandwidth and v.s.w.r. are also trade-offs, for example:
max v.s.w.r. of 1.5:1 gives 2% bandwidth
max v.s.w.r. of 2:1 gives 4% bandwidth

Other typical parameters include:

Power handling	300 W mean at 2 GHz 200 W mean at 4 GHz 100 W mean at 20 GHz	
Typical sidelobes	E plane H plane	12 dB down 18 dB down
Impedance		50 ohms

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Please send further information on items ticked:-

- ☐ **Microwave Aerials**
- ☐ **Eimac Planar Triodes**
- ☐ **Ferrite Limiters**
- ☐ **Extended interaction oscillators**
- ☐ **Rare-earth cobalt magnets**
- ☐ **Computer aided design**

Brochures (see page 1)

- ☐ Introduction to pulsed crossed field amplifiers.
- ☐ Effects of system breakdown on crossed field amplifiers.
- ☐ Cooling systems for high power klystrons.
- ☐ Microwave tubes operating hazards.
- ☐ Training manual on power klystron amplifiers.
- ☐ Introduction to coaxial magnetrons.
- ☐ Introduction to dither tuned magnetrons.
- ☐ Rare earth cobalt magnets.
- ☐ Frequency agile magnetron story.
- ☐ The care and feeding of power grid tubes (Price £1.75 post free).
- ☐ The coaxial magnetron, its theory and operation in fixed and agile modes (Price £2.50 post free).

Airline Quality Triodes

Offering reliable, long-life operation and guaranteed for 4,000 hours, the new Eimac 8906AL planar triode is ideally suited for high altitude airborne radars (TACAN/DME), even under the most adverse conditions.

Designed for use as a grid–or plated-pulsed oscillator or amplifier up to 3 GHz, the 8906AL features rugged ceramic metal construction, low interelectrode capacitance, high transconductance and high mu. An arc resistant cathode assures stable, reliable long-life operation under adverse conditions and minimizes catastrophic failure due to arc-over during circuit malfunction.

The 8906AL is derived from the 7815AL/7211/7698 series and incorporates that series' longer grid-anode ceramic insulator for high altitude airborne service. In addition, the new improved tube features a 60% larger cathode area than the 7815/7815A type, thus lowering cathode current loading per unit area while maintaining as high or higher current capability.

Operating conditions for the 8906AL planar triode in representative application.

Pulsed grid oscillator

Frequency	1.090 GHz
Heater voltage	5.7 V
DC plate voltage	2000 V
DC grid voltage	-75 V
Peak plate current	1.1 A
Peak grid current	0.8 A
Pulse duration	0.5 μs
Duty cycle	0.001
Power output (approx)	850 W

Pulsed plate oscillator

Frequency	1.1 GHz
Heater voltage	5.7 V
Peak plate voltage	2000 V
DC grid voltage	-45 V
Peak plate current	2.0 A
Peak grid current	1.0 A
Pulse duration	3.5 μs
Duty cycle	0.001
Drive power	300 W
Power output (approx)	2000 W
Gain	8 dB
Plate efficiency	50%

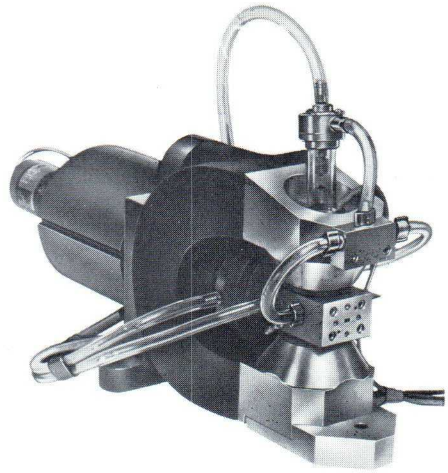
MILLIMETER POWER IN WATTS

Forget the milliwatt as a measure of power at millimeter wave-lengths. Varian's extended interaction oscillators (EI0's) have changed all that. Some models deliver up to 50 watts, others operate at well over 100 GHz. And they last too, many have mean times between failures of well over 5000 hours.

Three series are available:

1. **High power fixed tubes:** These are fixed frequency EI0's with outputs from 50 watts at 60GHz to 1 watt at 140GHz.
2. **High power tunable EI0's** are oscillators with outputs up to 15 watts, tunable over about 5GHz at 75GHz (shown here).
3. **Long life low voltage EI0's** are designed as pump sources for state of the art low noise, uncooled parametric amplifiers. Tunable over 2GHz, these EI0's typically give 1 watt at 75GHz.

The highest power EI0 so far constructed is the VKE 2401, a fixed frequency, 60 GHz, 50 watt, c.w. tube which has operated for over 3000 hours with very little change in performance. The warranty for the VKE 2408 is 2000 hours or 1 year, and all the others have warranties of 1000 hours or 1 year.



Extended Interaction Oscillators

Type	Frequency	Power into matched load	Tuning: Mechanical	Tuning: Electronic
VKE-2401A	50-80GHz	35W.	Fixed	150MHz
VKE-2408A	70-80GHz	1W.	1GHz	150MHz
VKE-2409A	50-80GHz	13W.	3GHz	150MHz
VKE-2409B	50-80GHz	13W.	3GHz	150MHz
VKE-2406A1	70GHz	15W.	2GHz	150MHz
VKB-2414A1	80-110GHz	10W.	Fixed	-
VKB-2415A1	80-110GHz	1W.	±500MHz	-
VKB-2410A1	80-110GHz	8W.	4GHz	150MHz
VKT-2413A1	110-140GHz	1W.	4GHz	-
VKT-2411A1	110-140GHz	1W.	4GHz	-
VKQ-2416A	35GHz	1kW (pulsed) 1W mean	Fixed	-
VKE-2412A	70GHz	10kW (pulsed) 4W mean	Fixed	-

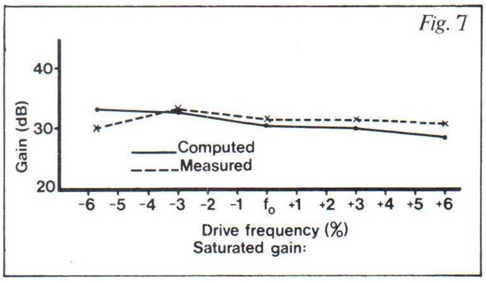
Warranty: VKE-2408 - 2000 Hr./1 yr. Others 1000 Hr./1 yr.

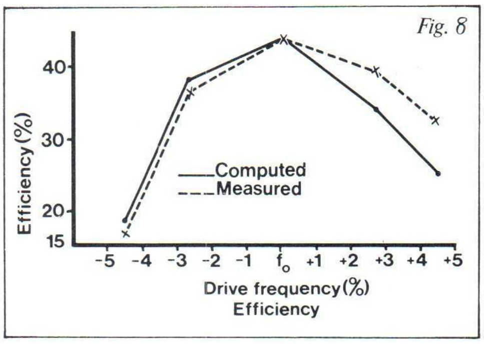
Optimising tube design by Computer

(continued from page 2)

is able to predict the hot performance of the finished tube extremely well, and a number of tube parameters can be varied, until an optimum design is obtained.

Figures 7 and 8 compare the measured and computed saturated gains and efficiency of a hybrid tube known as a twystron.





The knowledge and experience gained by EMI-Varian in computer aided design is available as a consultancy service, and has been used by industry, by government agencies and by universities.

EMI varian

To EMI-Varian Ltd.
248, Blyth Road, Hayes, Middlesex, England

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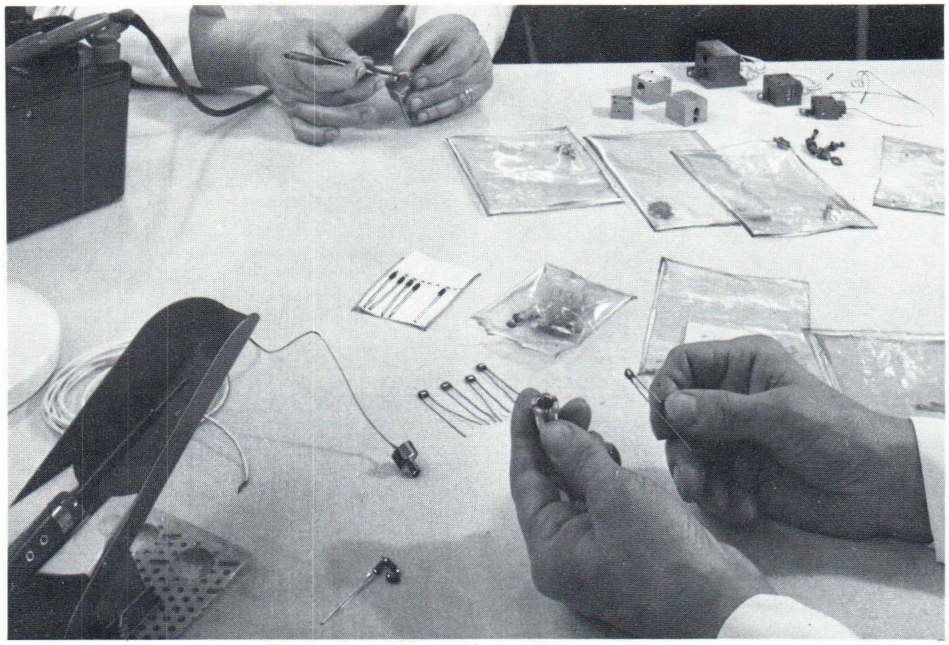
Microwave News

DEVELOPMENTS IN MICROWAVE TUBES AND DEVICES

Gunn effect oscillators

Following the discovery of microwave oscillators in gallium arsenide material by J. B. Gunn in 1963, Varian Associates established a special task force to work on the development of microwave power sources using the Gunn effect principles. The initial years of this programme were heavily concentrated on the development of gallium arsenide material with the proper purity concentration necessary for achieving operation in this fundamental mode. In 1967 both the material and diode fabrication techniques were sufficiently well-established to allow Varian to begin manufacturing and marketing Gunn effect diodes and sources.



Production of Gunn effect oscillators at Hayes.

The development of Gunn diodes and sources has been dictated by two primary factors; market demand and technical achievement. Thus c.w. devices have been developed to operate at C-band and above and pulsed sources have been developed to operate from L-band up to Q-band.

The simplicity of a bulk effect oscillator makes it a very desirable source of microwave power for local oscillators, parametric amplifier pumps, doppler radar transmitters, altimeters and distance measuring equipment where both narrow and broad band electronic tuned sources are required.

The formation of EMI-Varian in 1969 meant that for the first time Gunn effect devices could be supplied from the UK to the advanced specifications required by sophisticated applications.

A major reason for the superior performance of EMI-Varian oscillators is the Gunn diode used. The solid state division of Varian has for many years been using liquid phase epitaxial material (as opposed to vapour phase material). The significance of this is that EMI-Varian has achieved process control maturity well ahead of its competitors. All diodes are reproducible, each one is tested and guaranteed and each batch is practically identical.

Gunn effect oscillators

EMI-Varian offers an extensive series of Gunn effect oscillators which cover the frequency range of 4 to 60 GHz. These low-voltage devices can be supplied to meet rigorous military and commercial specifications as well as those required for less rigorous laboratory applications. The power output of these Gunn effect oscillators varies from 10 mW at 60 GHz to 300 mW at X-band frequencies. They can be supplied with either mechanical or electronic tuning – or a combination of both. Mechanical and varactor tuned EMI-Varian Gunn effect oscillators are capable of being tuned up to 10% of the centre frequency. Yig-tuned oscillators provide 40% or greater electronic tuning ranges.

Mechanically tuned Gunn effect oscillators operate from a single, regulated, low-voltage, dc power supply which provides bias to the Gunn effect diode. The electronically tuned oscillators require a second low voltage power supply either to provide bias to a varactor diode or to energize a Yig-tuning coil.

EMI-Varian Gunn effect oscillators offer exceptionally noise-free performance, comparable to that of good quality klystrons with similar degrees of tuning. The sturdy, compact construction and the excellent thermal properties of these Gunn effect diodes, coupled with extensive experience in the design and fabrication of microwave circuits, permits their operation under adverse environmental conditions.

General specifications for these devices follow. The user should bear in mind that these generalized tabulations do not, by any means, represent EMI-Varian's total capability in these areas. Specialized devices can be supplied upon request. *(continued page 2)*

Definitive Work on Magnetron Technology

"The Coaxial Magnetron – its theory of operation and application on fixed and agile modes", is a book produced by EMI-Varian, which is likely to become a standard text on modern magnetron technology. The book is based on a series of seminars on coaxial magnetrons held last May at the company's Hayes plant. Among the subjects discussed are: The theory and operation of the Coaxial Magnetron; The Coaxial versus the Conventional Magnetron; The Theory and Applications of Frequency Agility in Radar Transmitters; Dither Tuned Magnetrons and Magnetron Modulators.

The coaxial magnetron is so named because of the large coaxial cavity coupled to the resonators of the anode block. As it is explained in the book, this design concept leads to a high Q r.f. oscillator with vast improvement in performance as regards:– pulling, pushing, frequency stability, freedom from arcing and missing pulse, lifetime, MTI performance and MTBF figures. Tuning can be accomplished easily over wide ranges with no performance degradation and the tube can be reliably adapted for frequency agile use.

Since its development, the coaxial magnetron has achieved widespread acceptance in the United States, the vast majority of new magnetron radars in the USA being designed with coaxial tubes. EMI-Varian is the first British company to establish a manufacturing facility for these tubes.

The book "The Coaxial Magnetron", containing full illustrations, diagrams and references is available from EMI-Varian – price £2.50. (see coupon).

GUNN EFFECT OSCILLATORS

(Continued from page 1)

A. Mechanically tuned

Mechanically tuned Gunn effect oscillators display a power temperature coefficient specified as 0.05 dB/°C. Typically, the power temperature coefficient varies from 0.02 dB/°C at X-band to .04 dB/°C at Ka-band. Frequency coefficients are typically less than 0.002%/°C at X-band and 0.001%/°C at Ka-band.

Type no.	Frequency range	Tuning range	Power output minimum	Typical bias voltage	Typical bias current
1. VSX-9001	8–12.4 GHz	Up to ±500 MHz	25 mW	10 Vdc	300 mAdc
		Up to ±500 MHz	50 mW	10 Vdc	350 mAdc
		Up to ±500 MHz	100 mW	10 Vdc	400 mAdc
		Up to ±500 MHz	150 mW	10 Vdc	450 mAdc
		Up to ± 50 MHz	250 mW	10 Vdc	750 mAdc
2. VSU-9002	12.4–18 GHz	Up to ±500 MHz	25 mW	8 Vdc	300 mAdc
		Up to ±500 MHz	50 mW	8 Vdc	350 mAdc
		Up to ±500 HMz	100 mW	8 Vdc	400 mAdc
3. VSK-9004	18–26.5 GHz	Up to ±500 MHz	25 mW	7 Vdc	350 mAdc
		Up to ±500 MHz	50 mW	7 Vdc	400 mAdc
		Up to ±500 MHz	100 mW	7 Vdc	500 mAdc
4. VSC-9009	4–8 GHz	Up to ±250 MHz	25 mW	11 Vdc	350 mAdc
		Up to ±250 MHz	50 mW	11 Vdc	400 mAdc
		Up to ±250 MHz	100 mW	11 Vdc	500 mAdc
5. VSA-9010	26.5–40 GHz	Up to ±500 MHz	10 mW	4 Vdc	300 mAdc
		Up to ±500 MHz	25 mW	4 Vdc	350 mAdc
		Up to ±500 MHz	50 mW	4 Vdc	500 mAdc
		Up to ±500 MHz	100 mW	4 Vdc	1 Adc
6. VSQ-9021	40–50 GHz	Up to ±500 MHz	10 mW	4 Vdc	350 mAdc
		Up to ±500 MHz	25 mW	4 Vdc	350 mAdc
		Up to ±250 MHz	50 mW	4 Vdc	500 mAdc
		Up to ±100 MHz	100 mW	4 Vdc	1 Adc
7. VSE-9020	50–60 GHz	Up to ±200 MHz	5 mW	3.2 Vdc	500 mAdc

B. Varactor tuned

There exists a large number of possible combinations of electronic tuning, mechanical tuning and power output that can be obtained with EMI-Varian varactor tuned oscillators. A few examples of these combinations are shown below. Other possible combinations can be provided to ensure that the user obtains the optimum device for his particular application. Power output, power temperature coefficient, and frequency temperature coefficient can vary as a function of electronic tuning range and operating temperature range.

Type no.	Frequency range	Tuning* range, MHz mech.	elec.	Power min.	Typical Gunn bias voltage Vdc	Typical Gunn bias current mAdc	Tuning voltage Vdc, min.	max.
1. VSX-9011	8–12.4 GHz	±200	+30	25 mW	10	300	0	50
		0	+1000	25 mW	10	400	0	50
		±200	+200	50 mW	10	400	0	50
		0	+2000	10 mW	10	500	0	50
		0	+1100	20 mW	10	500	0	50
		±500	+100	50 mW	10	500	0	50
			+500	100 mW	10	600	0	50
2. VSU-9012	12.4–18 GHz	±200	+30	25 mW	8	300	0	50
		±200	+30	50 mW	8	350	0	50
		0	+1000	50 mW	8	400	0	50
		0	+2000	10 mW	8	500	0	50
		0	+500	100 mW	8	600	0	50
3. VSK-9014	18–26.5 GHz	±200	+30	25 mW	7	350	0	50
		±500	+100	25 mW	7	450	0	50
		0	+1000	25 mW	7	400	0	50
		0	+1000	100 mW	7	600	0	50
		±250	+500	100 mW	7	600	0	50
4. VSA-9015	26.5–40 GHz	±200	+60	25 mW	6	350	0	50
			+1000	50 mW	6	600	0	50
			+200	75 mW	6	650	0	50
			+150	100 mW	6	1200	0	50
5. VSC-9019	4–8 GHz	±100	+50	100 mW	11	500	0	50

* The frequency of varactor tuned oscillators increases as the varactor bias voltage is increased

C. Yig-tuned

EMI-Varian's Yig-tuned, solid state, Gunn-effect oscillator is designed for use in commercial and laboratory applications requiring a very wide electronic tuning range. These miniature, current-tuned devices deliver a linearly-swept c.w. output over X- or Ku-band without discontinuities. Only two, well-regulated, low-level supplies are required – a constant voltage input supply for the Gunn-effect diode, and a current supply for the magnetic tuning coil. Noise performance is far superior to thermionic devices with comparable tuning bandwidth. Special purpose versions, other than those listed below, can be supplied on request.

The VSX-9070 and VSX-9071 differ in that the VSX-9071 incorporates an additional, low inductance tuning ("tickler") coil to provide frequency modulation capability. In Ku-band, the VSU-9076 incorporates the tickler coil.

Type no.	Electronic tuning range	Power out min.	Typical Gunn bias voltage	Typical Gunn bias current	Max. tuning voltage	Max. tuning current
1. VSX-9070	8–12.4 GHz	10 mW	15 Vdc	450 mAdc	7.0 Vdc	600 mAdc
2. VSX-9071	8–12.4 GHz	10 mW	15 Vdc	450 mAdc	7.0 Vdc	600 mAdc
3. VSU-9075	12.4–18 GHz	5 mW	13 Vdc	550 mAdc	9.5 Vdc	850 mAdc
4. VSU-9076	12.4–18 GHz	5 mW	13 Vdc	550 mAdc	9.5 Vdc	850 mAdc

D. Special purpose rf packages

EMI-Varian special-purpose r.f. packages are designed to relieve the system engineer of the difficult task of overcoming system interface problems, or they can provide characteristics far superior to those attainable with a basic oscillator. The system designer, in the past, has had to try to specify the voltage regulators, circulators, isolators, oscillators, proportional temperature controllers, etc., to assemble in order to meet overall system performance characteristics of the microwave power source. This procedure is no longer necessary. The system engineer may now purchase a device to meet his overall system requirement simply by specifying the necessary parameters.

Examples of packages that have already been designed and manufactured are listed below.

1. Parametric amplifier pump source, VSQ-9035A

Centre frequency:	42 GHz
Mechanical tuning range:	±100 MHz
Power output:	75 mW, minimum
Input voltage:	12 to 15 Vdc 100 mV maximum peak-to-peak noise and ripple
Input current:	1.2 Adc, max.
Power temperature coefficient:	0.01 dB/°C, max.
Load v.s.w.r.:	1.3:1 any phase
Temperature:	60°C

2. Low-noise X-band Doppler illuminator driver, VSX-9031D

Fixed frequency:	X-band
Power output:	250 mW, minimum
Input voltage:	28 Vdc ± 1 Vdc
Input current:	2 Adc, maximum
Load v.s.w.r.:	1.5:1, any phase
Temperature range, operating:	0°C to 65°C
Frequency stability:	±50 kHz over temperature, load and input power variations
AM noise:	Less than 110 dBc in a 1 kHz bandwidth at spectral frequencies in excess of 3 KHz from the carrier
FM noise:	Less than 1 Hz, r.m.s., in a 1 kHz bandwidth at spectral frequencies in excess of 3 kHz from the carrier

3. YIG-tuned frequency source, VSX-9031

Electronic tuning range:	8.0 to 11.0 GHz
Power output:	20 mW, minimum
Tuning input voltage:	0 to 10 Vdc into 10k ohms
Tuning speed:	5 millisec, max., for full range
Tuning linearity:	±0.2% maximum deviation from straight line frequency versus analog input voltage
Size:	2¾ × 3.0 × 4⅝ inches including 28 volt Gunn diode bias voltage regulator and Yig tuning coil driver
Environment:	Military, airborne.

Frequency agile MTI systems with Accu-tune magnetrons

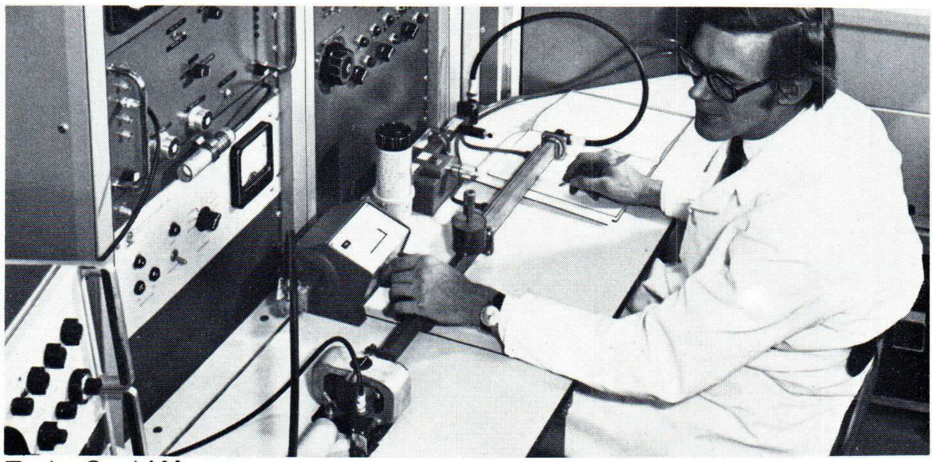
With EMI-Varian's new line of Accu-tune magnetrons, the operating frequency of radars can be changed with every scan of the antenna. Only 50 milliseconds are needed to tune 400 MHz in X band with MTI accuracy.

There is no need to sacrifice the reliability and stability of standard EMI-Varian coaxial magnetrons to get this exceptional tuning speed and accuracy. The Accu-tune mechanism is simply applied to any existing EMI-Varian coaxial magnetron, only slightly increasing its weight. The resulting magnetron needs only electrical inputs and has low operating power requirements.

Changeover is so simple that retrofitting to existing radars so as to add new capabilities is attractive.

Further, there is no limitation to pre-programmed, scan-to-scan agility operation with Accu-tune magnetrons. Other operating modes include fixed frequency or manual channel selection. Configurations can even be provided for full-band, pulse-to-pulse agility.

Accu-tune magnetrons are now available in X, Ku and Ka bands with peak outputs of up to 250 kW. Models at other frequencies or power levels are readily available.



Testing Coaxial Magnetrons

The first resistor stabilized transistor for 1 GHz Operation

The new Communication Transistor Corporation D20-28 power transistor offers the highest power available from a 24 to 28 volt supply over the frequency range of 400 to 1200 MHz.

The 20 watt device is the high power end of a four transistor complement, other models in the chain are the 1 watt D1-28 and the 10 watt D10-28.

Superior power/frequency performance is coupled with maximum reliability due to single chip construction plus the ability to withstand infinite v.s.w.r. at all phase angles when operated at rated output power and 24 volt supply.

XB50-28 wideband Power Transistor breakthrough

Another new addition to the CTC range is the XB50-28 a major breakthrough in the area of power gain, power output and ruggedness.

For years, circuit design engineers have sought to operate r.f. power transistors at UHF, with gains of 10dB or more, at power levels of 25 watts or higher.

CTC has found the right approach and now has available the world's first UHF, 50 watt transistor with 12 dB gain.

The XB50-28 represents the first of the rf power transistors for the systems of the "70's".

Data and details of circuit techniques are now available for these transistors from EMI-Varian Limited, together with wall charts outlining the complete CTC range to date.

THE WORLD'S MOST POWERFUL TETRODE

One tube will produce 2MW c.w. output, or switch 1000 amperes!

The X2159 tetrode now in production at EIMAC's San Carlos plant, can develop two megawatts of c.w. power up to 30 MHz or so, with up to 17 dB stage gain. It can also be used as a 60 kV 1000 ampere switch tube or as an extremely high power pulse modulator.

Two EIMAC X2159's can be used in a 2.5 megawatt, 100% plate modulated medium or short wave transmitter. At VLF moreover, two X2159's can develop 4 megawatts of c.w. power.

The X2159 has a two section thoriated tungsten cathode mounted on water cooled supports. The two sections may be excited in quadrature to reduce hum contributed by an a.c. power source. The maximum anode dissipation rating is 1,250,000 watts steady state.

In spite of these impressive electrical values, the external dimensions are:
Height: 23 inches; 58.4cm
Anode cooler diameter: 11.25 inches; 28.6cm
Mounting base (screen terminal) diameter: 17 inches; 43.2cm.

Provision is made for large diameter co-axial terminals to the control grid and three r.f. cathode terminals. Filament power and filament support cooling water connections are made through three special couplings with knurled threaded clamping rings.

This technological breakthrough permits a very high power broadcast transmitter to be built, having a single output stage. For the first time, 5 megawatts output, or greater, is a practical proposition.

Advantages of using these high gain tetrode tubes include: substantially smaller capital investment; driver stages, power supplies, control circuits, cabinets and floor space may also be substantially reduced.

Full data for this tube is now available.

Microwave components for 0·5-140 GHz

EMI-Varian has been engaged in the design, development and manufacture of both centimetric and millimetric high performance radar and telecommunication equipments for the last decade and a half. This has resulted in a fund of knowledge which is considered unique in Europe.

Two basic technologies have been developed. Ceramic microstrip integrated circuits are used for frequencies from 0.5-2.0 GHz, and precision millimetric microwave components are manufactured for frequencies from 20-140 GHz.

Microstrip Integrated Circuits.
Many robust components have been designed and manufactured, these include:–

(a) Balanced mixers
Using Schottky barrier diodes, these mixers cover the frequency range 0.4-20 GHz. Bandwidths of 10% or 30% are available. The conversion losses are typically 6 dB.

(b) High speed switches and Phase modulators
Both SPST and SPDT configurations. The switching times vary with power handling. Typical times are $< 1 \times 10^{-9}$ sec for 25 mW and 5×10^{-9} sec for 2 W.

(c) Low noise amplifiers
(i) Octave bandwidths from 1-2 GHz or 2-4 GHz with a noise figure of 5-7 dB. The gain is 35 dB.
(ii) Narrow band amplifiers with 20% bandwidth and a noise figure of 3.5-4 dB at 1 GHz. These amplifiers have a gain of 20 dB.

(d) High power amplifiers
Various power amplifiers are available with outputs from 6 W at 1.9 GHz to 20 W at 1 GHz.

A complete list of microstrip components is available.

Microstrip techniques on ceramic substrates offer substantial advantages. Reliable lightweight and very small units become possible, and cost less than the equivalent conventional systems. Many complete systems are manufactured to customers' requirements. Some standard sub-systems are also available. These include:–

(e) Microwave 'front ends'
Comprising a Gunn oscillator, a duplexer or circulator, a coupler and a balanced mixer.

(f) Intruder alarm 'front ends'
A low cost, small size microwave ceramic unit containing the r.f. source, mixer and aerials all integrated on a single 75×50 mm substrate. This unit is tailored for the highly competitive security market and is available for most of the European frequency bands.

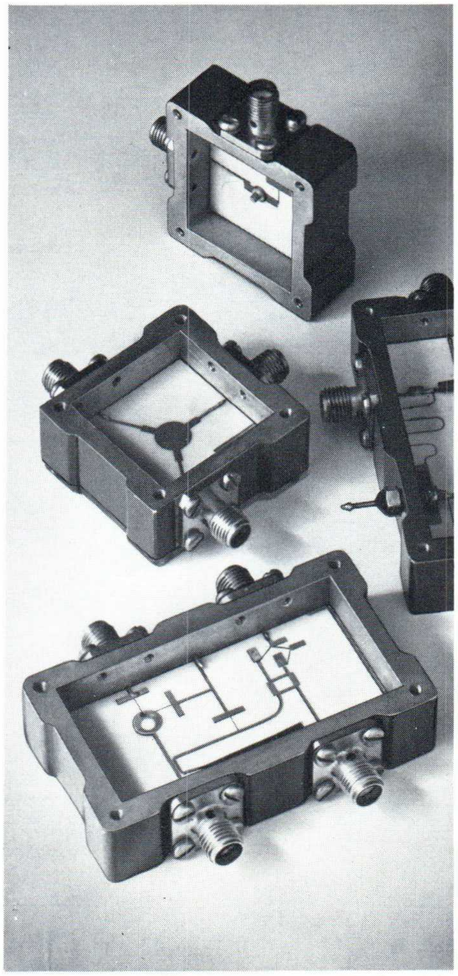
(g) Single sideband doppler generator
An integrated hybrid unit which performs the function of an 'on-line' calibrator for doppler radars.

(h) Aerials
A range of lamina aerials which are unique to EMI-Varian, cover from 1 to 35 GHz. They are intended as a low cost replacement for horns and small dishes. A typical example is an X-band 15° pencil beam aerial realized in a size of $120 \times 120 \times 10$ mm including its connector.

Millimetric Components
A range of waveguide components is available for frequencies from 20-140 GHz. As well as passive components such as low power precision attenuators, switches, bends, twists, tapers, filters etc., there is a range of active components. These include:–

(a) Mixers
Schottky barrier mixers are available, either single ended or balanced, from 24-170 GHz. Normally they are in waveguide sizes WG20, 22, 24, 26 and 28. Intermediate waveguide sizes are available, to special order. The conversion loss varies from 6.5 dB at 35 GHz to 12 dB at 90 GHz. These are the true a.c. operating figures and include all matching losses etc.

(b) Thermistor mounts
A series of broadband thermistor heads covers the frequency range 26.5-90 GHz. Individual calibration certificates are supplied with complete heads. Spare thermistor wafers are available.



(c) High power variable attenuators
A typical example of this range has a dynamic range of 20 dB and a power handling capability of 15 watts at a frequency of 75 GHz.

NEW MINIATURE TWT'S

EMI-Varian now offers a range of midget X-band travelling wave tubes which fit inside their appropriate waveguides!

These tubes are about 6 inches long and weigh approximately 6 oz, yet they give an r.f. output of 10-20 W at 8-12 GHz c.w. A conventional travelling wave tube giving a similar output at the same frequency weighs about 2½lb.

The key to this major reduction in size and weight is the new focusing magnets. These magnets are made of samarium cobalt, which enables high magnetic fields to be obtained from small magnets. The high magnetic fields obtained permit the tube itself to be designed to work at lower voltages and higher beam currents, so that the length of the new device is only half that of a tube with conventional magnets. The new magnet weight is only 20% of the usual magnet weight.

As well as the advantages which any lightweight system component has, the small size of these tubes gives extra flexibility to aerial designers. For a given r.f. power level, the effective radiated power is substantially increased by radiating the signal in a narrow beam. Very narrow beams can be obtained by adjusting the phase of the signals fed to each separate antenna element. EMI-Varian, miniature travelling wave tubes are so small that they can be packed at the same pitch as the antenna elements of an X band aerial, and it is relatively simple to adjust the input signal phase to each tube to obtain the required phase differences to each aerial element.

These miniature travelling tubes can also be operated in a dual mode, typically with a peak to c.w. power ratio of 2:1.

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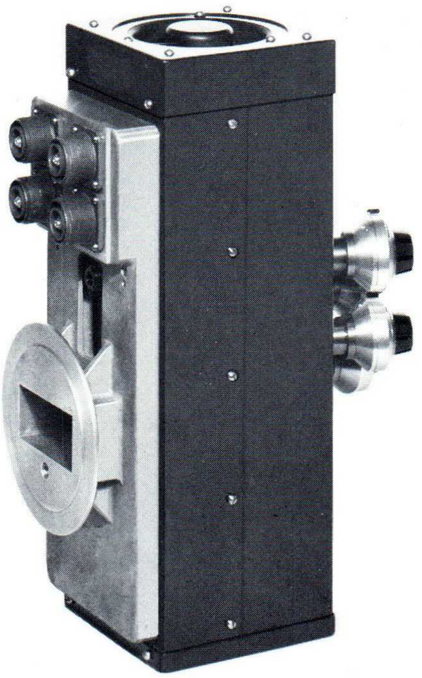
Microwave News

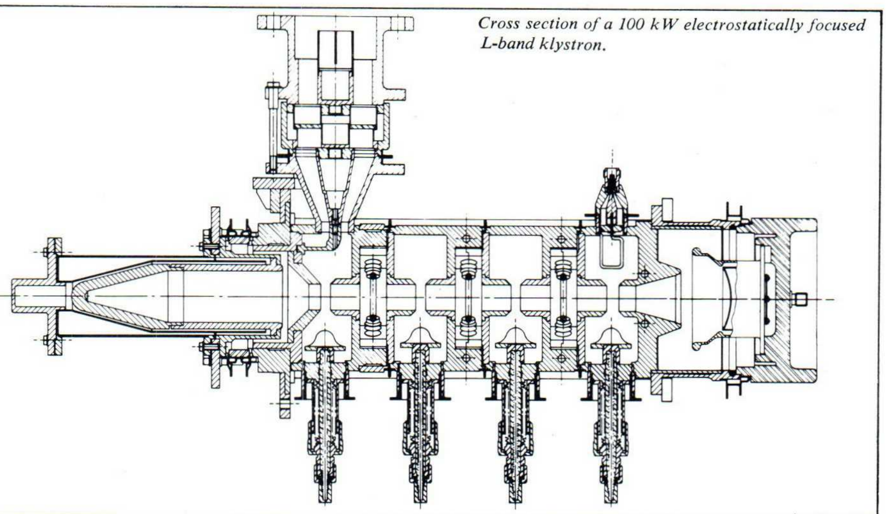
DEVELOPMENTS IN MICROWAVE TUBES AND DEVICES

Why the ESFK? Latest developments in electrostatically focused klystrons

The theory behind the klystron amplifier always assumes that there is a long stream of electrons with which the successive cavities can interact. The basic problem, therefore, in the design of any klystron, is to produce a uniform, laminar flow, electron beam and then to keep it focused along the length of the tube.



EMI-Varian PT 1010 2½ kW S-band electrostatically focused Klystron which is in full scale production.



Cross section of a 100 kW electrostatically focused L-band klystron.

The classic method of keeping the beam focused is to use a longitudinal magnetic field of sufficient strength to keep the beam "stiff". The outcome of this method is that the tube has to be fitted with electromagnetic coils or permanent magnets, the weight of which is often considerably more than the basic tube itself.

There is, however, another method of focusing a beam of electrons which has been known for a very long time, and that is by a succession of electrostatic Einzel Lenses which periodically refocus the beam. Einzel lenses consist of a circular electrode disposed between two other electrodes at a different potential, and have been used in electron microscopes since their invention. By choosing the geometry correctly, the lens in the klystron is made to work at the potential of the cathode, and the adjacent electrodes, which form part of the tube body, at earth.

The spacing between successive lenses is such that the electron beam is refocused to approximately the same diameter. Each successive lens is a repeat of the first.

The klystron cavities have to be designed to fit in between the lenses and, at the same time, enough clearance has to be allowed in order to bring the correct voltage onto each lens without breakdown occurring. The ability to achieve success depends very much on how good the manufacturer's technology is, as high voltages have to be stood off across small spaces, and cleanliness and assembly accuracy are essential.

If electrostatic klystrons are so much lighter and therefore easier to handle than their equivalent magnetically-focussed counterparts why is it that they are a comparatively recent development? The answer lies in the complexity of the calculations required to design an electrostatic Einzel lens system for a dense beam of electrons, in which the effect of space charge cannot be neglected.

The problem was first solved by building a planar network of resistors graded as the distance squared from the base line; by this means, the potential of any point in the network simulates the free space potential of any electrode system set up on the network in cylindrical symmetry. If this potential is fed to an analogue computer, Laplace's equation for an electron at that point in the network may be solved, and the motion of the electron calculated. This process is repeated for every square in the network through which the electron passes, so that its complete movement through the system can be determined. The process is repeated for a number of electrons in the beam; space charge is then introduced by feeding in additional currents to the network and the calculations repeated until the calculated beam and the beam represented by the space charge currents are identical.

It is also possible to carry out the above procedure using only a digital computer, but the network analogue method is still preferable, when the electrode configuration is completely unknown to begin with, as electrode modifications are quick and simple.

continued on back page

Mixing Microwaves

EMI-Varian have introduced a series of microwave mixers giving frequency coverage from 400 MHz to 140 GHz. Designated MIC 1 for frequencies up to 20 GHz and MMC 10 for above this frequency, these mixers are designed for use in microwave based equipment such as radar, telecommunications networks and security systems.

Like other types of modular integrated circuits, a particular advantage of these miniature devices is that they contribute towards a significant reduction in the size, cost and weight of microwave equipment. Both series of mixers use Schottky-barrier diodes and are suitable for heterodyne and homodyne use over a wide range of intermediate frequencies. Other main features include wide instantaneous bandwidths and low noise figures.

EMI-Varian in Multiplex TV transmission breakthrough

Although a klystron can be used in its multiplex mode to amplify both sound and vision television signals to high power levels, this mode of operation has not proved convenient up to now. The gain characteristic of a klystron is not linear at high power levels, and in the multiplex mode this non-linearity causes both intermodulation distortion of the vision signal and cross modulation distortion of the sound signal. Normally cross modulation is not objectionable, but intermodulation distortion can be.

The C.C.I.R. recommendation that intermodulation products should be at least 51 dB down on peak sync has in the past been achieved be de-rating the klystron so that it worked on the linear portion of its characteristic. This has meant in practice that power amplification by klystrons in the multiplex mode has only been considered reasonable as a stand-by condition.

In recent experiments an EMI-Varian klystron was run in the multiplex mode in conjunction with a pre-corrector unit developed by Electromechanical Enterprise of Budapest (EMV). The experiments established that a significant reduction in intermodulation distortion was possible.

Demonstration of EMI-Varian 55 kW Klystron with EMV pre-corrector unit.

Using the EMV pre-corrector unit, type number TCK.1715, a VA 953A 55kW klystron, operating in the multiplex mode, amplifies sound and vision signals to over 25 kW peak sync., giving clean signals. All the intermodulation products are more than 51 dB down. Moreover the klystron beam energy conversion efficiency is increased to 17.5% and the klystron gain under these conditions is over 50 dB.

Even better results have been obtained at lower power levels. For example between 10 and 20 kW peak sync, using a VA 950A the worst intermodulation product is 56 dB down, and the efficiency remains 15-17.5%. Thus it is now possible to use EMI-Varian klystrons efficiently under multiplex conditions for both transmitters and transposers.

EMI-Varian manufacture a wide range of klystrons for television transmitter application with power levels ranging from 10 to 55 kW peak sync.

New TR Cell has 10,000 hour life

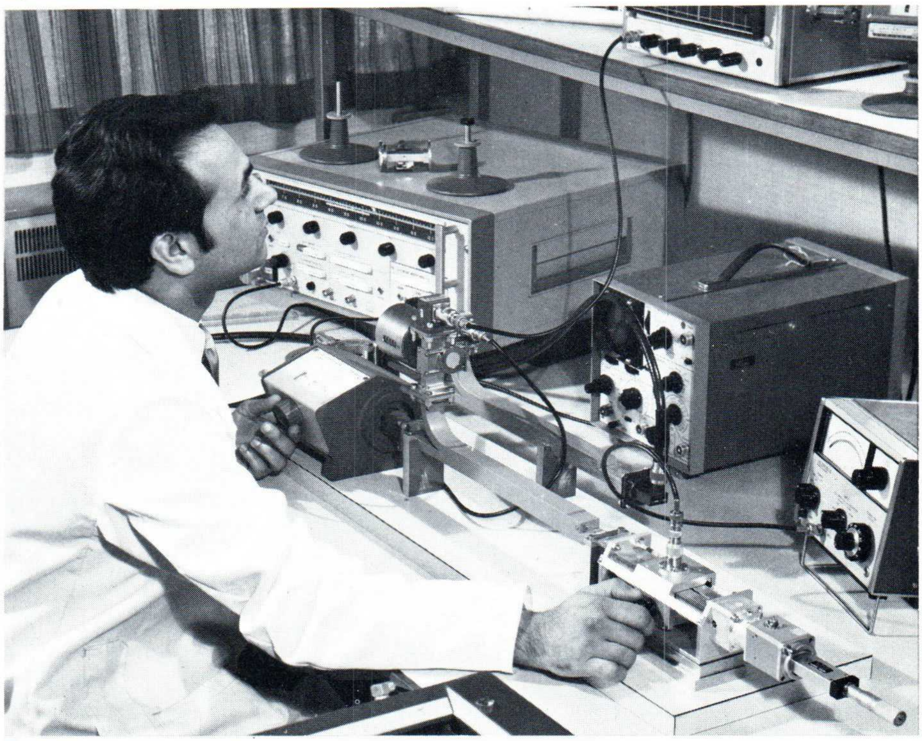
EMI-Varian are now able to supply solid state ferrite/diode limiters to replace the conventional TR Cell. Ferrite/diode limiters exhibit very fast recovery times and exceptionally long life, in excess of 10,000 hours.

Units are available in S, X and J-band. They are passive devices consisting of a ferrite limiter for handling high power, and diode limiter for reducing spike and flat leakage power to levels which assure reliable receiver protection. These units are complete solid state replacements for many gas-type TR Cells.

The VFS-9501 S-band unit is rated 2.9-3.1 GHz but can be supplied for operation over other 200 MHz bandwidths within the frequency range of 2.7-3.5 GHz.

The VFX-9503 X-band limiter covers the frequency range of 9.3-9.6 GHz, but can be supplied over other 300 MHz bandwidths within the frequency range of 8.5 to 10.0 GHz.

The VFU-9502 J-band limiter is a 15.8 to 16.2 GHz device, also available in any 400 MHz bandwidth within the range of 15.8 to 17.2 GHz.



Testing TR Cells at EMI-Varian

Characteristics	VFS-9501	VFX-9503	VFU-9502
Frequency range	2.9-3.1 GHz	9.3-9.6 GHz	15.8-16.2 GHz
Peak Power, max.	15 kW	50 kW	15 KW
Recovery time, max.	1.0 μs	0.2 μs	0.2 μs
Recovery time, typ.	0.5 μs	0.1 μs	0.1 μs
Insertion Loss, max.	0.8 dB	1.0 dB	1.5 dB

Impatt Diodes and Oscillators

EMI-Varian impatt diodes and oscillators cover the range from C to K band with power levels in excess of 1 Watt. When operated in a reverse bias condition these devices generate microwave power due to a locally established avalanche zone followed by a suitable drift space. The diode junction capacitance and drift space are optimised to yield exceptionally clean r-f power along with high d-c to r-f conversion efficiency within the specified output frequency range. In all EMI-Varian diodes special care has been taken to ensure the best thermal conduction from the silicon chip.

EMI-Varian impatt oscillators are used as local oscillators, low power transmitters and parametric amplifier pumps in military and commercial monopulse, CW and doppler radar. These highly reliable solid state oscillators are supplied in both high Q and low Q circuits. Both high Q and low Q oscillators can be mechanically tuned up to 1 GHz at X-band and wider tuning ranges can be supplied on request.

EMI-Varian can also supply an injection locked oscillator in amplifier packages comprising the driver source and all associated components and power supplies. These devices provide very wide tuning ranges with high power outputs and the systems engineer has simply to provide an r-f drive to a varactor-tuned Gunn oscillator in the package.

New Transistor Range

Communications Transistor Corporation are an affiliate of the EIMAC division of Varian, and were formed solely to manufacture rugged RF power transistors specifically for land mobile and communications applications. These transistors are now available in the United Kingdom through EMI-Varian.

All CTC transistors are single chip devices to overcome multiple chip matching problems, and will withstand infinite VSWR at all phase angles when operated at rated power and supply voltage.

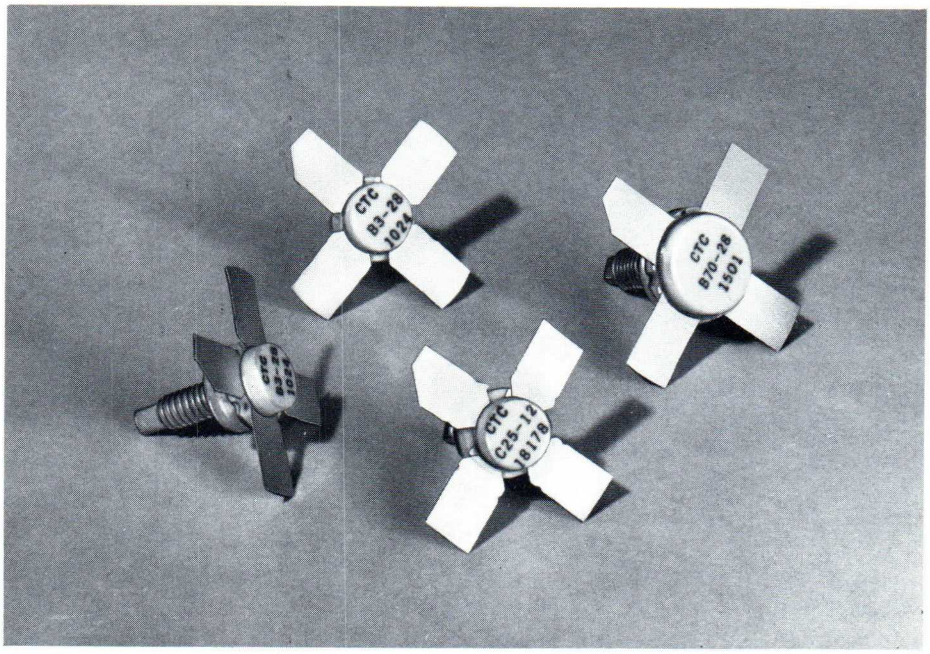
Each device is mounted in a 4 lead ceramic/metal stripline package to keep emitter lead area to a maximum so minimising lead inductance.

CTC relies primarily on the interdigitated structure to obtain high frequency performance. Extensive work at CTC has demonstrated that the interdigitated structure is the most effective of all structures evaluated for RF performance, ruggedness, reliability, consistency and ease of manufacturing. To ensure optimum thermal performance, multiple base structures are employed and all designs are evaluated by IR scanning. CTC's DIBAR thin film resistors are used to distribute emitter current so preventing "hot spot" formations.

Types currently available range from 70 Watt devices at HF to 10 Watt complements at 2 GHz operating off 8, 12 and 28 volt supplies for use in both military and civil applications.

Data sheets containing full electrical and mechanical details including complete test amplifier circuitry are available. Each test amplifier is easily reproduceable and incorporates inexpensive readily available components. In some cases actual size photographic layouts are included to show exact component placement for duplication should the need arise.

Reliability is the key to CTC's aims, and to achieve this end transistor fabrication and testing is undertaken with the newest and best equipment available today.



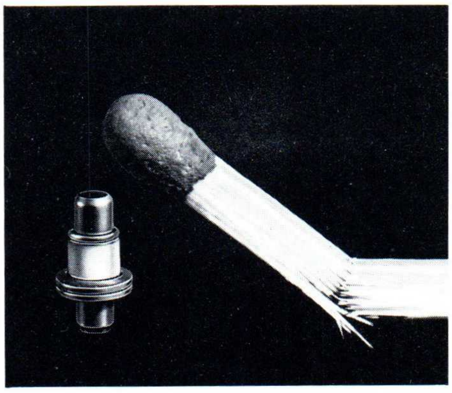
Broad based Magnetrons

EMI-Varian offers the widest selection of coaxial magnetrons available in the world today and is the only company actively engaged in the U.K. manufacture of these devices. Coaxial magnetrons are supplied in either fixed tuned, tunable or frequency agile (dither) versions.

In S and C band we can offer fixed frequency and tunable tubes up to 2 MW power levels suitable for radar and accelerator work. X and J band tubes comprise, fixed frequency types for weather radar applications, tunable tubes to cover all or part of the radar bands, and tubes for frequency agile systems. The frequency agile or dither tuning is designed to be compatible with the system requirements in nearly all modern radars. Power levels range from tens of kilowatts to one megawatt.

In Q band the inverted coaxial magnetron design concept has led to performance and lifetime improvement not achievable with any other type of magnetron. Fixed frequency, tunable, and frequency agile tubes can again be supplied with frequency up to 40 GHz.

EMI-Varian coaxial magnetrons have the longest lifetime and generally lowest cost per operating hour of any kind of transmitter tube. We offer warranties of up to 5000 hours on many types of tubes and 1500 or 2000 hours are typical warranty figures.



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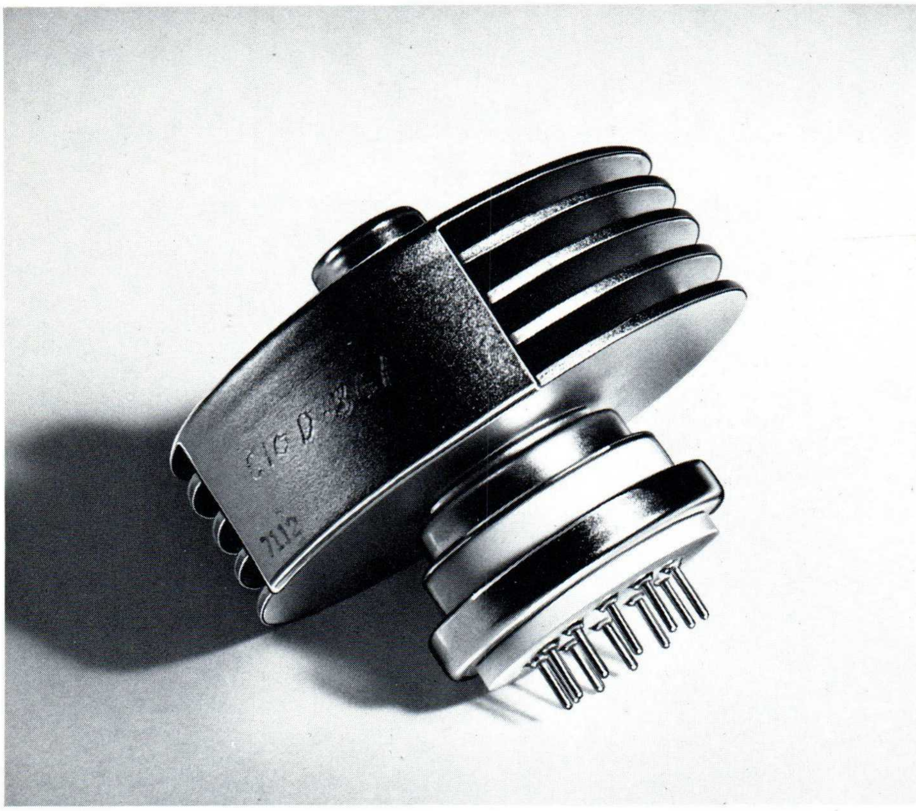

EIMAC HF/VHF/UHF

Some interesting new additions to the EIMAC range of power grid tubes have recently become available for new equipment designs, some of which are listed below.

Intended as a replacement for the well tried 4CX 5000A tetrode is the X 2152, a ceramic-metal, air-cooled power tetrode intended for use at the 10-15kW output power level. It is recommended for use as a Class C, RF amplifier or oscillator, a Class AB, RF linear amplifier or a Class AB, push-pull, AF amplifier or modulator. The air-cooled anode is rated at 5kW dissipation.

At a 10kW output level, 20 dB of gain enables the X 2152 to be driven directly from a power transistor. Consequently 10-15kW FM transmitters for example, can be built with all solid state drive.

The zero bias family of EIMAC tubes forms an extensive range of triodes from 15 to 50kW anode dissipation for final amplifiers and drivers, FM broadcast transmitters, RF heating oscillators etc.

No bias and screen supplies are needed for these tubes, and neutralisation is not necessary below 100 MHz because of the isolating effect of the grounded grid.

Other advantages of this line of triodes include high efficiency, high gain, and good linearity; up to —35dB IMD cathode driven. Typical of these is the air cooled 8874 with segmented cathode for low grid interception. For a fraction of the cost of an equivalent tetrode-socket combination, the 8874 yields over half a kilowatt as a class AB_2 RF linear amplifier.

EIMAC also offer the most complete range of linear tetrodes available today covering 350 watts plate dissipation up to the 50kW level. Third order IMD/products of —40dB or better are achievable with these tubes which were designed primarily for HF SSB communications use. Typical types are the 4CX 5000J and 4CV 50,000J, both thoriated tungsten mesh filament tubes with specially designed grids for maximum linearity.

The X-2159 super tetrode can develop two megawatts of CW power up to 30 MHz or so with up to 17 decibels stage gain. It can also be used as a 60 kilovolt, 1,000 ampere switch tube, or as an extremely high power pulse modulator.

Two Eimac X-2159's can be used in a 2.5 megawatt, 100% plate modulated medium or shortwave transmitter. At VLF, moreover, two X-2159's can develop 4 megawatts of CW power.

continued from page 1.

Why the ESFK?

What are the design limitations? There is already a technological complexity to the lens region; extra metal-to-ceramic seals are needed, and care has to be taken to allow an adequate safety margin for the voltage hold-off gaps. This constraint will limit the peak power capability of the klystron and as klystrons become smaller as the frequency increases, the limitation reduces with increasing frequency. 300 kW at L-band, 100 kW at S-band and 10 kW at X band are well within design capabilities.

When the beam is modulated, a proportion of the electrons will be travelling at a velocity below that produced by the H.T. voltage. These electrons will find it difficult to pass through the last lens, particularly if they appear near the edge of the beam, because of the potential barrier formed by the lens. This results in some of the rf current in the beam being lost, with a reduction in klystron efficiency. This loss can be minimised by keeping the beam filling factor low (below 60%), and electronic conversion efficiencies of around 35% can be obtained.

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Microwave News

DEVELOPMENTS IN MICROWAVE TUBES AND DEVICES

Whatever happened to the magnetron?

Coaxial devices transform the reliability picture.

Mode control is the key to improved magnetron reliability and the invention of the coaxial magnetron, a combination of a magnetron with a TE011 mode cavity to acheive this mode control has lead to an enormous improvement in magnetron reliability.

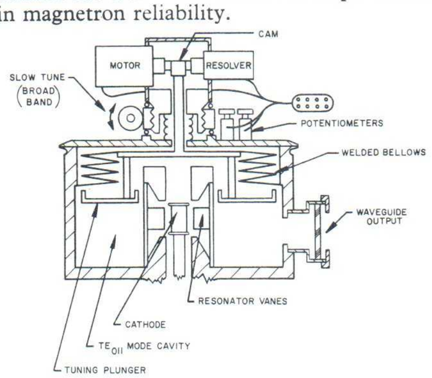


Figure 1
Schematic of dither tuned magnetron.

The TE011 r-f electric field exists in a circular form only and does not extend from one metal surface to another. Current flow in

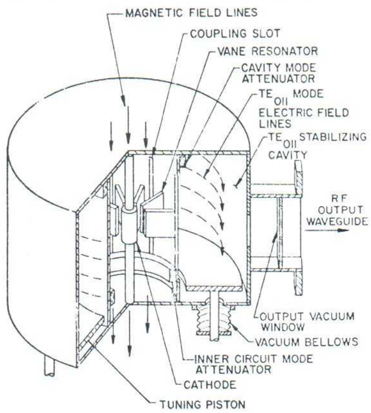
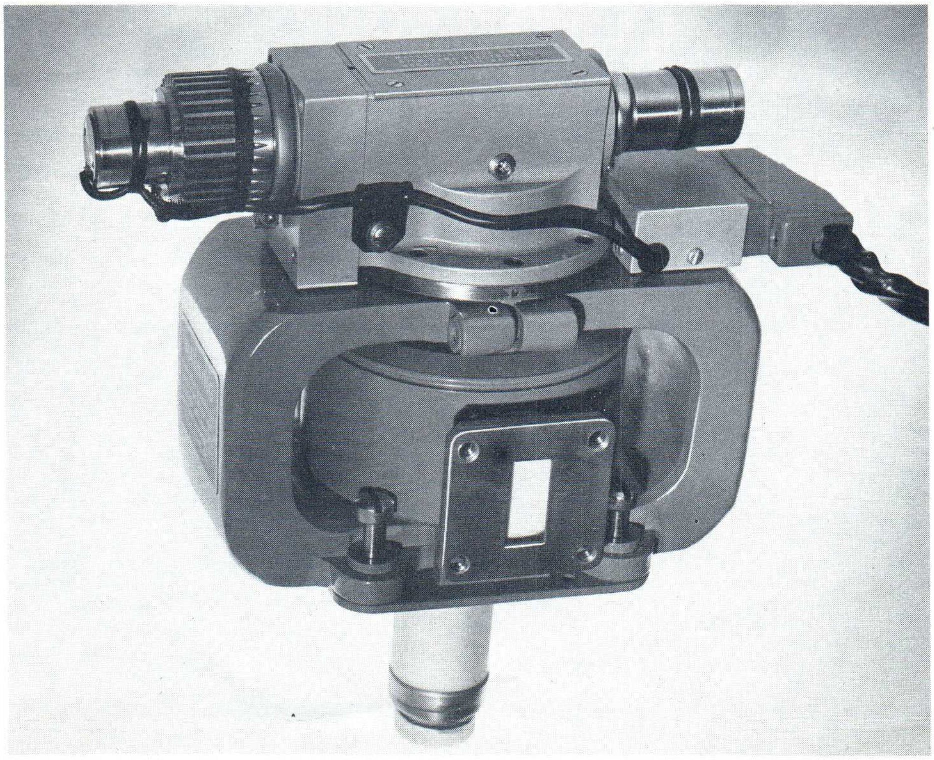


Figure 2
Cutaway view of coaxial magnetron.



the walls of the TE011 cavity is lower than in other modes and also has a circular path. This is significant in the design of a tuner for this cavity. If an end plate is made to move in the cavity, the frequency is changed without interrupting lines of current flow. This is illustrated in the cutaway section of the tube in Figure 2. The ability to tune without interrupting current makes the coaxial magnetron tuner the most reliable tuner for any magnetron.

Circular current also permits the design of attenuators which selectively dampen unwanted modes without affecting the desired TE011 mode. One method is to insert a suitable attenuator in a groove at the junction of the inner cylinder and fixed end plate of the cavity. Currents in other modes couple to this attenuator, thereby suppressing unwanted mode oscillation. Unwanted modes of the inner resonators are attenuated in a similar manner. The inner resonators are coupled to the TE011 mode cavity by a series of slots. To a π mode, there are only half as many slots as there are vanes. Current in the TE011 mode is guided by these slots into the central vane area as shown in the illustration. The ends of the slots are free of TE011 mode current. An attenuator, located at the ends of the slots within the inner slotted cylinder, selectively dampens the undesired modes of the vane area.

What has been done? No frequency separation devices such as straps are required. Damping of unwanted modes can be realized without hurting the desired mode and is not dependent on the waveguide or other external load. No limitation has been placed on the size of the interaction area or the number of resonators that can be used. The designer now can proceed to design the tube with as many resonators as are needed to produce a conservative design. The cathode is not overloaded and no excessive voltage gradients occur. Adequate dissipation in the vanes is assured. Furthermore the need for system waveguide match (low VSWR's) and system bandwidth is changed. The coaxial magnetron will tolerate higher systems VSWR's and will require a system waveguide bandwidth no greater than its tuning range.

A second design approach has also been successfully reduced to practice. It was known that a magnetron could be built with the anode and cathode inverted – that is with the cathode surrounding the anode. However, no practical commercial inverted tube had appeared on the market. Here again, the basic problem of mode suppression had prevented its use. To build the inverted coaxial magnetron, the cavity was located inside a slotted cylinder and a resonator vane array was arranged on the outside. The cathode was built as a ring around the anode.

continued on page 2

Modes were controlled by internal selective attenuators in much the same way as the coaxial magnetron.

The success of this approach extends the useful range of coaxial magnetrons to millimetre wavelengths.

Advantages of Coaxial Magnetrons

Invented to improve reliability, the coaxial magnetron gains many other advantages from the stabilizing cavity.

The TE_{011} cavity mode is a low loss of resonant cavity mode and therefore the Q of the cavity is at least an order of magnitude greater than the Q of a multi cavity conventional magnetron. As a consequence of this the oscillating frequency of the magnetron has much greater stability, i.e. the effects of both internal and external impedances cause only small changes of frequency.

For this reason the pulse to pulse frequency jitter is reduced by about an order of magnitude. As the pushing factor – the effect of voltage pulse and current pulse changes on the magnetron frequency, and the pulling factors – the effect of the load reactance on the magnetron frequency, are both much reduced, the magnetron spectrum is much improved.

A comparison of typical results on a conventional 200 kW X-band magnetron the 7008 and its coaxial replacement the SFD 349 is shown in the table below.

	7008	SFD349
Efficiency	38%	38%
Leading edge jitter		
typical	1.5ns	2.5 ns
Pushing factor		
specified	400 kHz/A	100 kHz/A
typical	200 kHz/A	50 kHz/A
Pulling factor		
(V.S.W.R.1.5:1)	15 MHz	5 MHz
Spectra side lobes	8-9 dB	12-13 dB
6dB (Bandwidth		
spec)	2.5/tpc	2.0/tpc
(Typical)	2.2/tpc	2.0/tpc
Missing pulses	1%	0.1%
Pulse frequency jitter		
r.m.s.	85 kHz	10-15 kHz
Life spec	500 h	1250 h
typical	700-800 h	3000-3500h

Tuning.

Most modern radar systems require the transmitting tube to be tunable either to avoid interference with other radar or guidance systems; or in more sophisticated systems fast tuning is used to reduce clutter and glint.

Conventional magnetrons can be tuned with complicated tuners which increase their tendency to arc and introduce losses into the multicavity resonators: because of the complications very few of them are tunable.

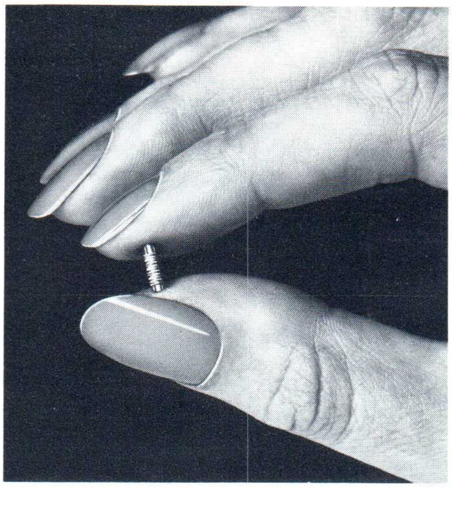
In contrast, the coaxial magnetron has a simple TE_{011} cavity as the frequency determining cavity and the fields in this cavity are such that a tuning element is very easily included without loss of tube performance. The tuning element is indicated in figure 2.

Because of the ease of tuning, almost all designs of coaxial magnetron are available in tunable versions.

For frequency agile systems, one must be able to move the tuner through a small distance rapidly and repeatably. EMI- Varian get this movement by using an element proved reliable in sewing machines since our grandmothers' time – the cylindrical spindle rotating off its main axis. This type of frequency agile tuning is called 'Dither tuning' and has proved as reliable in use as in the sewing machine. A schematic of a dither tuned coaxial magnetron is shown in figure 1. The dither tuning cam is driven by the electric motor, the tuner position and therefore the frequency being indicated by the voltage output of the resolver. This read-out is a single voltage output which is linear with the frequency excursion to better than 2%. Its simplicity compares very favourably with the complexity of accurate frequency determination in other types of frequency agile tuning.

New Stackpack® diodes

50 Watts in L-band



The Varian Stackpack Diode consists of two high efficiency bimode diode chips combined in a series stacked configuration.

Each diode chip is housed in its individual beryllia package and both packages are then brazed into a single unit. Thus the packages are connected electrically in series and thermally in parallel. Power-handling capability is greater than that of a single diode because the area of each diode junction is larger by the number of units connected in series.

These diodes are designed for frequency multiplication, conversion, and modulation in telemetry and point-to-point microwave transmission applications where high power and efficiency are required.

In addition since these diodes combine the advantages of fast transition time and high breakdown voltage, they are especially suited for high-power step-recovery-multiplier and impulse-generator applications.

Typically these diodes can give 50 Watts output power at L-band and 5 Watts at X-band.

Select Your Water Load

EMI-Varian are supplying four different types of water loads, all of which have a low VSWR and are conservatively rated. Most are capable of maintaining gas pressure, many can be used in evacuated waveguides, and all are designed for convenient installation and reliable operation.

Selection of a water load for a particular application is normally based on many system considerations. With the three waveguide types available, trade-offs in features are possible so that most applications can be accommodated by a standard load. The basic design of these standard loads produces a maximum VSWR of 1.15:1 over the following bandwidths:

Teflon Wedge	30–40%
Ceramic Block	12–16%
Glass Tube	50–75%

Ceramic Block loads utilise a ceramic block window as a dielectric step transformer to match the impedance of the waveguide to that of water. The water acts as both the attenuator for the RF and a means of removing the heat.

Ceramic loads are miniature, light in weight and have a very high average power capability, they are also extremely rugged. However the bandwidths are limited and the inlet coolant range is 10°C to 60°C.

Teflon Wedge loads are similar in basic principle to the ceramic block type. The primary difference is a linear taper of teflon employed as a broadband matching device which allows the use of ethylene/glycol and/or water. This family of loads has lower average power and is heavier than the ceramic block but the bandwidths are much greater. They are very rugged.

Glass Tube loads are not as rugged as the ceramic block or teflon types, they are larger and are limited in pressure and temperature capabilities. Their broadband feature makes them ideal for laboratory use.

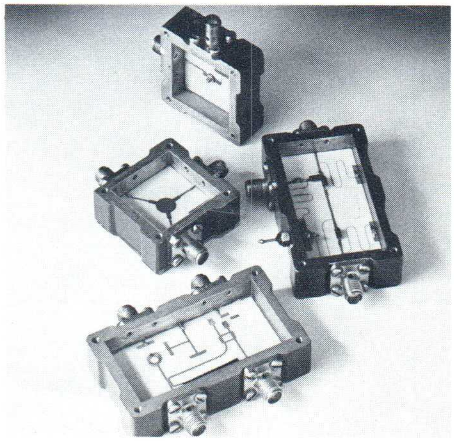
Although the emphasis is on standard loads, we are always glad to design special loads to meet unusual requirements. For example, lower values of VSWR can be provided for narrow band units.

Modular MIC's to 20 GHz

Space saving, weight saving, cost saving EMI-Varian microstrip circuits provide the engineer with a flexible low cost technique for breadboarding microwave integrated circuits. Filters switches, aerials, mixers, amplifiers, phase shifters, transmitter/receiver units are available operating up to and beyond 20 GHz. The latest techniques in microstrip circuitry on ceramic substrates are used in the manufacture of these modules to ensure reliability and repeatable performance.

A feature of the techniques used is the ease with which various combinations of these circuit units can be integrated on a common substrate. For instance MIC4, a CW Transmitter Receiver unit comprises a 10 mW Gunn Oscillator, a 6dB Balanced Coupler and a Balanced Mixer integrated in to a unit 61mm × 36mm × 15mm.

In addition custom engineered MIC packages of the highest complexity can be readily produced using the EMI-Varian computer design facilities.



Eimac Planar Triodes

Extended Life

EMI-Varian offers a comprehensive range of Eimac miniature triodes suitable for pulse and CW operation up to 6 GHz. Typical applications include airline transponders, airborne distance measuring equipment, altimeters, military TACAN's, small airborne radars, surveillance radars, interrogators, television translators, collision avoidance radars.

Some of the latest types:

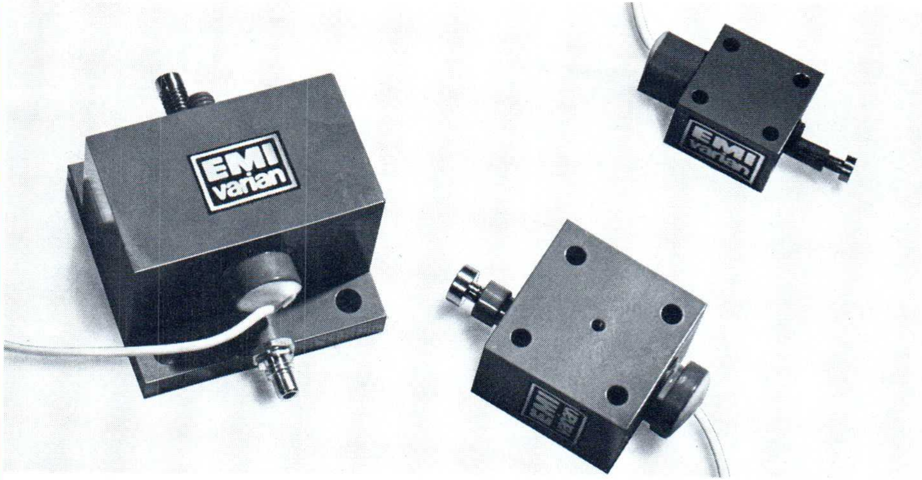
1. The 8906/8907 AL were recently introduced for commercial airline avionics as long life replacements for the 7815AL type and now are in use by many airlines in distance measuring equipments and transponders. Warranty period is 4000 hours compared to the 2000-3000 hours for the 7815AL.

2. Another long life tube, the Y579 is intended for TV translator service. Life times for this 100W S-band tube are expected to be in the region of 10-14,000 hours.

New developments for translator service include the X2162 which is designed to yield 300-500W into S-band, and further dispenser cathode developments should yield 1 kW CW.

3. Eimac's new family of miniature planar triodes (8892, 8893, 8911, 8912 and Y594) has generated much interest for use in new circuit designs up to C-Band. Design features of these tubes include a woven mesh grid structure which enables tube to operate despite arc damage, which in conventional parallel wound grid structure would cause catastrophic failure. These tubes are able to withstand extreme environmental conditions and are readily adaptable to easy cavity and strip-line circuit mounting. All these tubes incorporate "spewing shields" which inhibit the deposit of cathode material on the tube walls, which in conventional tubes provides an alternative path to the RF output so reducing useful available output. Life in excess of 2 to 3 times that of conventional tubes has been recorded. Eimac have also redesigned older types of tube to incorporate this facility, notable of which is the 7211/7698.

Life tests were initiated in September 1969 using standard and long life 7211's. On



Gunn Oscillators

EMI-Varian offers a complete range of CW Gunn-effect oscillators for low power transmitters, local oscillators and laboratory use covering a frequency range from 4 to 60 GHz. Mechanical, varactor and YIG tuned models come within the range.

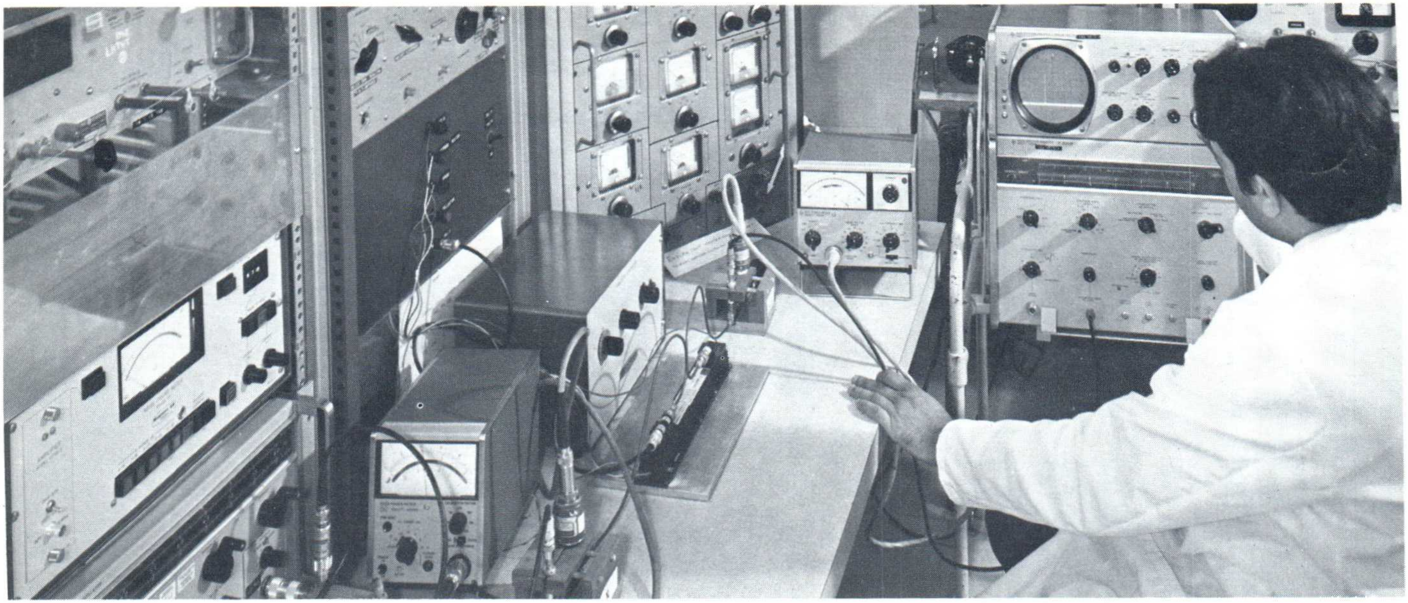
All devices offer low noise performance coupled with low voltage operation, rugged construction and extraordinary life expectancy.

FM noise characteristics are comparable to those of reflex klystrons and AM noise characteristics are superior. With the exception of the YIG devices none of the oscillators requires more than 500 milliamperes for operation. Life tests performed to date indicate an MTBF in excess of 100,000 hours.

Varactor tuned versions of the Gunn oscillator range can be supplied to customer requirements where electronic frequency control is important—such as tracking transmitter drift or stabilizing to a reference frequency. Typical of the

mechanical tuning range selected between 8 & 12.4 GHz. The VSU 9012 delivers a similar output between 12.4 and 18 GHz. Both oscillators can be tuned 30 MHz above their mechanical setting by applying a positive dc voltage to their varactor diodes. Two voltage supplies are required, a very low dc bias voltage supply for the Gunn effect diode and a low dc voltage for the varactor diode.

The new VSX 9070 is a YIG tuned solid state Gunn-effect oscillator for use as an X-band signal source in applications requiring very wide electronic tuning range. This miniature, current-tuned device delivers a linearly swept, CW output of at least 10 milliwatts from 8.0 to 12.4 GHz without discontinuities. Only two well regulated low-level supplies are required, a constant voltage input supply for its Gunn-effect diode and low current supply for its magnetic coil. Noise performance is far superior to thermionic devices of comparable



Our TWT's provide the ideal combination of gain, bandwidth, low noise and size.

Double - reversal permanent magnet focusing of TWT's provides an excellent compromise between weight and performance for wide-band, high-gain, low-noise amplifiers. They are within one pound of the weight of the lightest higher noise figure ppm types, and have noise figures only 1.5 to 2.5 dB higher than the lowest noise cumbersome straight-field types.

The range of drpm travelling wave amplifiers available from EMI-Varian represents the state-of-the-art development. In the table below except as noted, all units have a $2\frac{3}{8} \times 2\frac{3}{8}$ inch cross section. High-gain versions are $10\frac{1}{2}$ inches long and weigh approximately 5.2 pounds. Low Gain versions are only $9\frac{1}{2}$ inches long and 4.2 pounds in weight. All types have integral power supplies.

With proper shielding, double-reversal-focused travelling wave tubes can be operated side-by-side without spacing between units. Since the shield makes up a significant portion of the package weight, a careful design is required to optimize size, weight and performance. In some cases, reducing the external dimensions of the shield actually results in increased weight, since larger magnets may be required to make up for shunting effect of the shield. Also, the shield thickness may have to be increased to reduce the external fields to an acceptable level. Some weight can be saved by using heavy shielding only in critical parts of the package such as the gun region.

	Frequency (GHz)	Noise Figure (dB)	Gain (dB)	Power Output (dBm)
VTS–4350	2–4	8.0	25/40	13
VTG–4320	2.6–5.2	8.0	30/40	10
VTC–4360	4–8	8.5	25/40	14
VTH–4370	5–11	9.5	40	14
VTH–4370	7–11	9.0	50V	15
VTX–4380	8–12	9.0	50	15
VTX–4380	8–12	9.0	40	14
VTX–4382*	7–11	10.5	37	13

*2 × 2 *inch cross section*, $11\frac{1}{2}$ *inches long*, 4 *pounds*

CUT ALONG DOTTED LINE AND RETURN COUPON TO EMI-VARIAN

Microwave News

DEVELOPMENTS IN MICROWAVE TUBES AND DEVICES

C.F.A's move out of the lab.

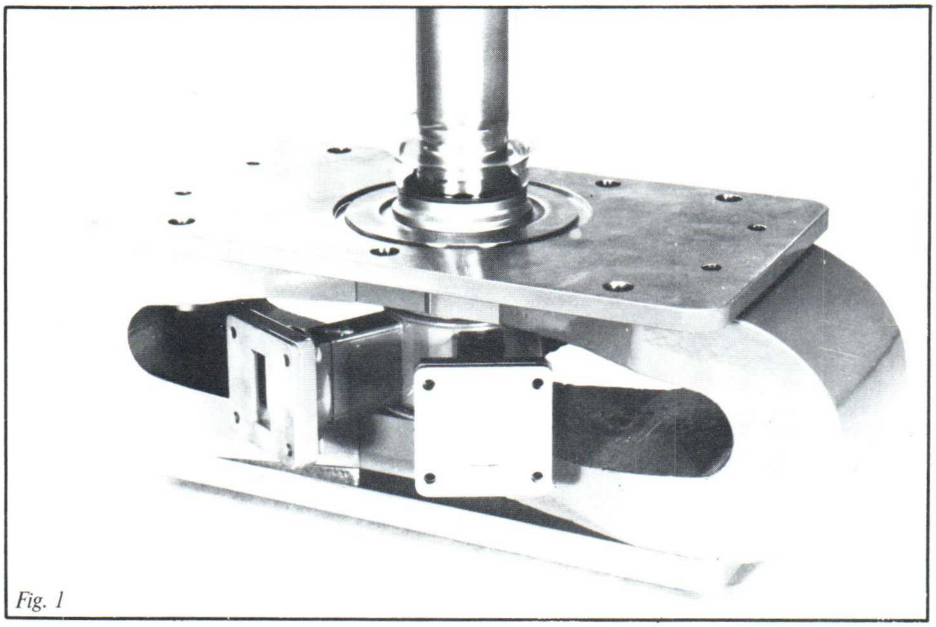


Fig. 1

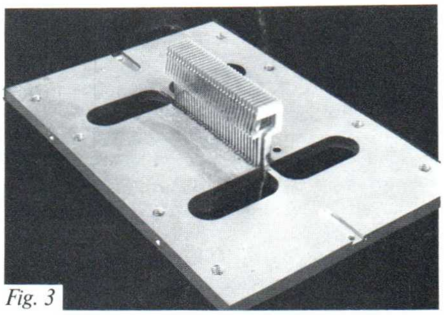


Fig. 3

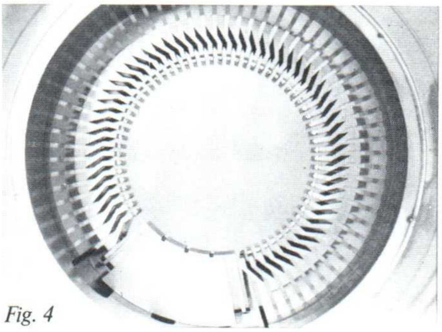


Fig. 4

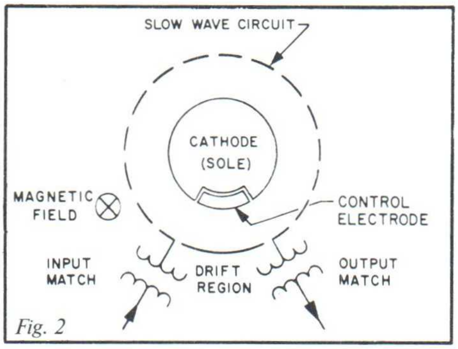


Fig. 2


Fig. 5

The crossed field amplifier (c.f.a.) is no longer a laboratory curiosity. Amplifiers are now being delivered for equipment use. Characterisation of these amplifiers has progressed well beyond gross performance parameters of power, gain, bandwidth and efficiency in order to determine the suitability of the c.f.a. for moving target indicator, pulse compression and possible paralleled or phased-array operation. Environmental capability and life have been evaluated on several programmes and the mechanical design of the c.f.a. can be made to comply closely with the transmitter requirements.

The c.f.a. derives its name from the fact that electronic interaction occurs in a region of crossed electric and magnetic fields, like the magnetron. This form of interaction distinguishes the c.f.a. from the conventional travelling wave tube. Otherwise the c.f.a. is made up of the same basic elements as a t.w.t. It has a slow wave circuit, and input-output system, and an electronic system. This article describes the contribution Varian Associates has made to c.f.a. technology and specifically to the forward and back wave re-entrant types without feedback. The c.f.a.'s referred to use an interaction circuit of circular format with distributed emission and not injected beams.

A schematic of the c.f.a. is shown in Figure 2. Original tubes had the output and input circuit sections nearly adjacent to each other to permit the modulated electron stream to re-enter the input region, adding its r.f. current component to that of the r.f. input signal. Varian modified this approach by removing the r.f. modulation from the re-entrant electron stream by imposing a drift region between the input and output. This provided freedom to increase the length of the slow wave circuit without curtailing bandwidth.

Some efficiency was lost but efficiences of 50% could still be realised. The significant improvements bought about by this development were an increase in gain-bandwidth product and greater power handling capability as a result of the longer slow wave circuit.

As early as 1960, Varian had demonstrated d.c. operation of a pulsed amplifier to introduce a technique which would simplify modulation requirements in many applications. A control electrode or quench electrode was added to the c.f.a. on the cathode assembly. This control electrode is isolated from the cathode so that it can be pulsed positively, at the end of the r.f. pulse, to intercept the electron stream and terminate operation. This turn-off pulse requires a much lower energy level than would be needed in cathode-modulated operation. As an example of this pulsed d.c. operation, one instrumentation radar generates 1 μsec pulses of 1.0 MW peak output power with a pulse-to-pulse spacing of 2 μsec. Pulse lengths and pulse spacings can easily be changed. Tubes using this technique are now operating in field equipment.

Varian also introduced the family of helix-derived c.f.a. circuits, which provide the necessary mixture of helix-type bandwidth with the power handling capability which is essential to c.f.a. design. The circuits come in many forms from the stub-supported helix for modest power levels (fig 3) to the helix coupled vane circuit for moderate power levels, and the helix coupled ladder line for high power levels (fig 4, 5). (continued overleaf)

(continued on page 2)

(continued from page 1)

With these designs and their variations there is a wide range of design capability to meet most system requirements. The stub-supported helix at S band, for example, covers the 1 to 5 kW average power range, the helix-coupled vane circuit covers the 5 to 15 kW range and the helix-coupled ladder line covers the 10 kW and up, range. Some examples of the capability of the present c.f.a.'s are given below.

Phase coding ability:
In phase-coded operation, the phase switching may result in a momentary drop in r.f. input signal level, leaving in question the amount of noise the c.f.a. might generate during the switching interval. A test was made in which a notch of 3dB of input r.f. level was made for 80 n.s., to simulate the phase switching. No additional spurious noise was observed. The spectrum did not visibly differ from normal.

Missing pulses:
Missing pulse counts have proved to be almost unnecessary in c.f.a.'s because they are r.f. driven and do not build up an oscillation from noise. Counts of 60 minutes have been made with 0 missing pulses out of over 2.3 million total pulses. To do the count properly, a double coincidence should be used to assure the presence of both r.f. input and modulator pulses before an output missing count can be made.

Cathode systems:
For lower levels of r.f. outputs, a new cold-cathode system has been developed and shown to have high reliability. The oxygen supported beryllium cathode has been operated for many thousands of hours without cathode failure. Cathode lives of 10,000 hours are feasible with this cathode system. The use of paralleled c.f.a.'s further increases system reliability.

Snap-on stability:
The use of a cold cathode has led to speculation that some time may be required before the pulse train establishes itself with stability. While some tubes do undergo minor performance changes with warming up after snap-on, the pulse train is well established from the first pulse. A storage scope view of the first 30 pulses of a train after snap-on shows only amplitude variations attributed to a modulator-power supply transient (figure 6).

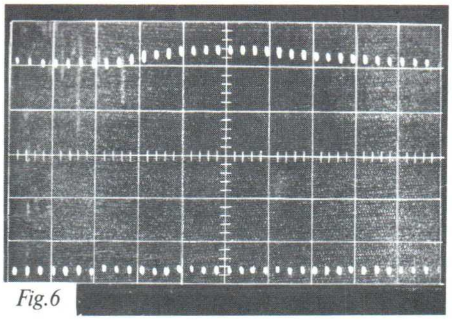


Fig.6

Intraspectral noise:
This measurement, which is difficult at best, is currently being simulated under the assumption that noise spectral density immediately outside the signal spectrum is nearly the same as that within the spectrum. Correlation has been established to this effect within 3 to 5 dB. Values measured in this way range from 45 dB/MHz to 60 dB/MHz.

Harmonic output:
Measurement of harmonic output is also very difficult, but a simulation of system conditions can lead to a useful indication of harmonic levels. In the measurement the c.f.a. is operated into a high power circulator which is followed by a series of tapers to waveguide beyond cut-off for the fundamental and the second harmonic.

The insertion loss of the system is measured at fundamental, second, and third harmonic frequencies. In the first waveguide, beyond fundamental cut-off, the total output above the cut-off frequency can be measured (second and higher harmonics). In the second waveguide beyond second harmonic cut-off, the third and higher harmonics can be measured. Values for second harmonic and higher have been 34 to 35 dB down and third and higher harmonics have been 42 to 55 dB down. The uncertainty in the measurement lies in not knowing the waveguide mode in which the harmonic energy is launched from the c.f.a. and whether or not that would lead to different values of insertion loss from those obtained by calibration. But the approach seems to simulate what would be encountered in a system, neglecting the effect of the antenna upon the effective radiated power of the harmonics.

Environmental capability:
Environmental tests have successfully been completed on an operating c.f.a. through a temperature humidity cycle, shock and vibration, confirming the ability of the c.f.a. to meet system requirements.

Magnetron booster application:
C.F.A's can be used as power boosters for dithered or frequency agile magnetrons. The spectrum of a dithered magnetron operating with a c.f.a. adds 10 dB or more to its output. Small differences in the spectra are observed because the output pulse from the c.f.a. has a shape modified slightly from the input r.f. by the c.f.a. modulator pulse.

Research and development continues to achieve higher gain while preserving the efficiency, low voltage and weight advantages of the c.f.a.

Improvements in Modern Klystrons

In recent years, techniques have been developed to increase klystron efficiencies to levels normally expected from magnetrons or other crossed field devices. The detailed choices of cavity and drift section parameters, as well as the use of second-harmonic impedance and beam space-charge forces, have given efficiencies for fixed frequency klystrons as high as 65% to 70%.

For example, the VKS-7773, a 50 kW tube has achieved 70% efficiency for industrial heating applications. It is a fixed tuned tube. The X-3074, a 100 kW fixed frequency tube, has also achieved 70% efficiency. In order to achieve appreciable tuning range however, some sacrifices in design parameters must be made and efficiency is somewhat reduced.

Lightweight focussing:
Electrostatic focussing:
The power supplies and coils required for electromagnetic focussing weigh far more than the klystron does. Permanent magnet focussing is lighter because no power supplies are required, but the weight is still significant. Electrostatic focussing, on the other hand, adds only a few grammes to the klystron weight, requires no extra power supply, and uses negligeable power. For example the PT1010, (Figure 1) a tunable S-band klystron giving a peak output of 2.5 kW, has three electrostatic lenses. These work at cathode potential, and only require a milliamp or so to keep them charged. All three lenses, together with their insulators only weigh 100 gms.

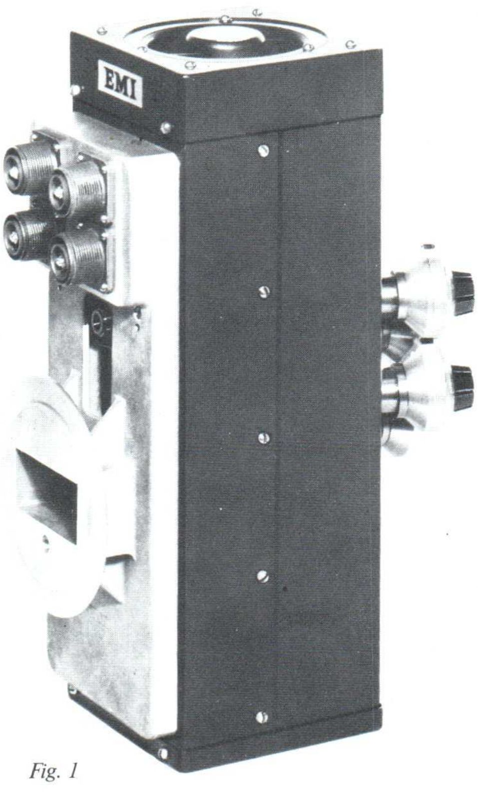


Fig. 1

The EMI-Varian electrostatic lens system has the added advantage of being truly robust, and these klystrons have successfully passed every vibration and environmental test required by the M.O.D.

PPM design:
Periodic permanent magnet focussing, commonly used in travelling wave tubes, has only recently been applied to klystrons as well. Normal klystron cavity spacings are too long to form acceptable magnetic lenses. New techniques such as floating pole piece sections in drift tubes between principal pole pieces have largely overcome this difficulty. A number of periodic permanent magnet focussed klystrons are now available or under development. For example, the VKX-7752, a pulsed klystron, operates in the 9 to 10 GHz range and can give 500 watts mean and 120 kW peak pulse power. The weight of this tube is only 9 pounds, compared with 35 pounds for a similar permanent magnet focussed klystron. PPM-focussed klystrons are currently under development for airborne and space applications because of their great weight advantage.

Samarium cobalt magnets:
Samarium cobalt magnets have a much higher magneto-motive force per unit length than the alnico type magnets and therefore a much smaller and lighter magnet can be used. Typical weight saving in the magnetic circuit is in ratio

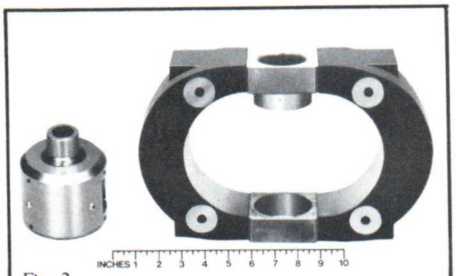


Fig. 2

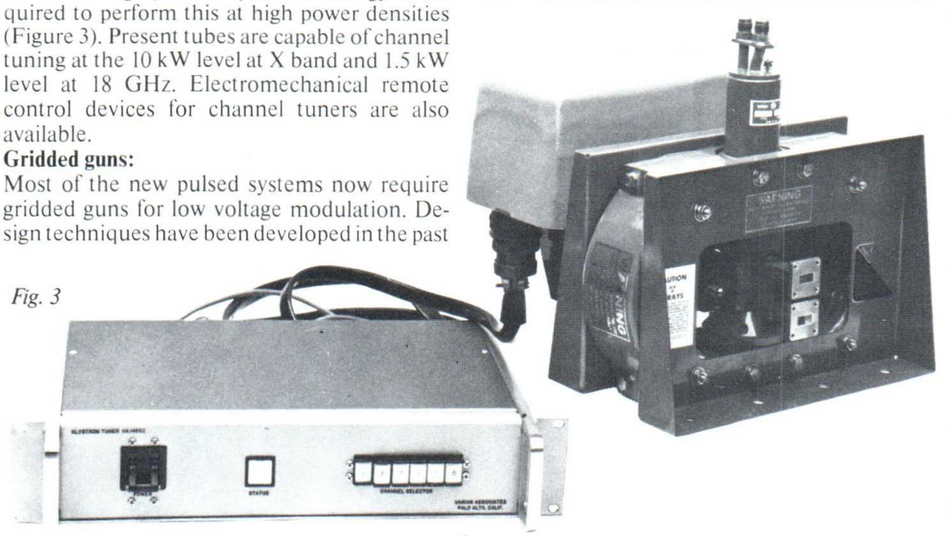
of 10 to 1 (Figure 2). These samarium cobalt magnets are therefore used for light weight, permanent magnet focussed klystrons and PPM travelling wave tubes. Their use in PPM focussed klystrons is being considered, but present limitations are the relatively high cost of the magnets and the sizes available. This focussing method will become increasingly important in the next few years as magnet prices drop.

Channel tuning at high power:
Typical klystron bandwidth at these power levels is about one percent which, however, is tunable over any frequency range of interest. In older designs, individual hand tuning of five or six cavities was required. In recent years, Varian has developed methods for rapidly tuning klystron amplifiers to any preselected frequency. This is known as channel tuning.

Any channel can be set by a simple motion of one or two knobs. Tuning is effected by mechanical motion of cavity walls with sliding contacts. Highly developed technology is required to perform this at high power densities (Figure 3). Present tubes are capable of channel tuning at the 10 kW level at X band and 1.5 kW level at 18 GHz. Electromechanical remote control devices for channel tuners are also available.

Gridded guns:
Most of the new pulsed systems now require gridded guns for low voltage modulation. Design techniques have been developed in the past

Fig. 3



few years for non-intercepting (shadow grid) guns suitable for use in high peak and average power tubes. The VKC-7790 is tunable from 4.4 to 5.4 GHz and has 55% efficiency. These designs are based upon non-linear computations of the interaction mechanism at saturation, requiring extensive computer programs as well as practical experience with many high-efficiency tube designs.

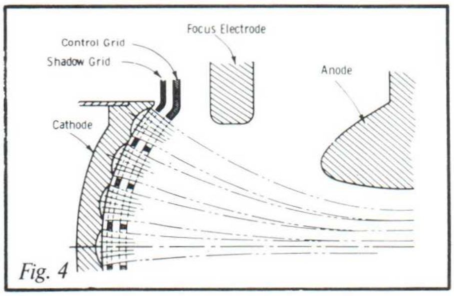


Fig. 4

Beam modulation is accomplished by two closely spaced, aligned grids, one of which operates at cathode potential. Unlike conventional designs, the Varian gridded gun has fairly massive grids with many round apertures aligned with corresponding spherical dimples in the cathode surface (Figures 4 & 5). This technique leads to excellent focussing characteristics and very uniform cathode loading compared with the conventional design.

The grid construction is very rugged mechanically and electrically and lends itself to design of compact high power guns. Average r.f. powers of up to tens of kilowatts have been achieved in S-band tubes with gridded guns. These guns are also widely used on travelling wave tubes.

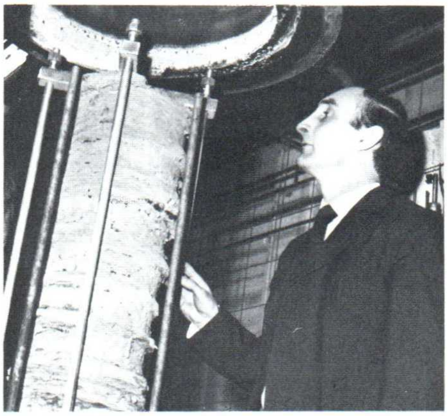
Fig. 5

Naval History helped by modern furnacing techniques

Until recently, conservation techniques for the preservation of weathered metallic relics of history have been limited. The corrosion salts and products can be partially leeched out by soaking in sodium sesqui carbonate for a number of years, but the resulting artifact continues to corrode at a reduced rate. A new application of an old technique, reduction, turns rust back to iron. It can be preserved for all time by plastic impregnation. This reduction of iron oxides and iron chlorides formed after years at sea, can be carried out by high temperature hydrogen treatment.

Henry VIII's pride and joy, the "Mary Rose", sank in battle in 1545 near Spithead. Recently, parts of its armaments have been brought up from the sea bed, and restored for Portsmouth museum by this method. EMI-Varian have just undertaken the restoration of a gun barrel, 4′ 2′′ long and 12′′ diameter in a hydrogen furnace that is normally used in the production of modern high power electron tubes.

The rusty barrel of the cannon was heated in a hydrogen furnace in a mixture of nitrogen and hydrogen to drive off the residual moisture. As the temperature increased, a large amount of hydrochloric acid gas was given off, while, at the same time, the surplus moisture was drained away from the bottom of the furnace. Over a period of four days the temperature was gradually raised to 1,050°C, and sustained for eight



E. R. Harvey, Manager, Technical Services, inspects the gun barrel after treatment.

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(continued from page 3)

hours to ensure that the treatment would be complete.

Mr. O'Shea, of the City of Portsmouth museum, considers that after this treatment is completed by vacuum impregnation, using a specially formulated plastic resin to seal the cavities in the metal, the cannon will keep for evermore. So confident is he of this, that Mr. O'Shea plans to instal a hydrogen furnace at the museum in the near future.

L-Band klystron rated at 5MW peak power:

A new 5-cavity pulsed klystron, the VA-963A, for use as a pulse amplifier in L-band systems requiring a simultaneous high level of output power, gain and efficiency is now available from EMI-Varian. The tube is particularly well suited for application in air traffic surveillance radar systems.

Capable of producing a peak power output of at least 5 MW over its tunable frequency range of 1.28 to 1.35 GHz, the VA-963 also provides a saturation gain of 50 dB or more and a typical efficiency of 40%. The tube simultaneously provides ample 1 dB bandwidth which, typically, is 35 MHz over the tuning range.

In addition, tuners located on the upper mounting plate are equipped with factory installed and calibrated digital cavity-tuning indicators for simple, fast and precise tuning. Integrated random noise and peak spurious output are at least 60 dB below the carrier level.

Conservatively designed with rugged construction to offer long life and reliable service, the VA-963 is electromagnetically focussed and both the tube and magnet are liquid-cooled. The mechanical design of the tube incorporates features to facilitate economic repairs.

Typical Characteristics.

Frequency range	1.28–1.35 GHz
Output power, peak	5.25 MW
Mean output power, max.	11 kW
Drive power, peak	50 W
Pulse duration, beam	3 μs
Gain, at saturation	50 dB
Efficiency	40%
Bandwidth, 1-dB	35 MHz
Beam voltage, peak	130 kV
Beam current, peak	101 A
Beam power, average	15.8 kW

The above typical characteristics reflect testing for a particular application. Other variations of the basic tube parameters can be accomplished for other applications.

Impatt Power Amplifier

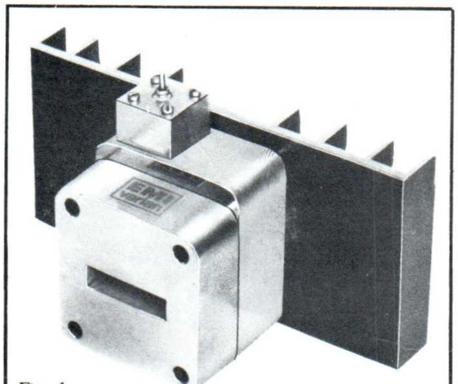
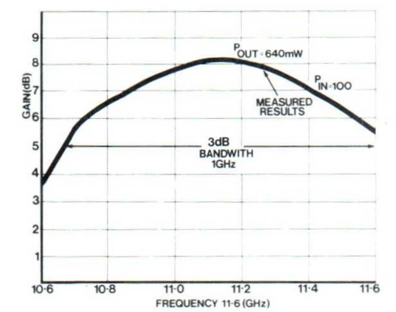


Fig. 1

Negative resistance amplifiers are available from EMI-Varian Limited for use in digital line-of-sight microwave links in the 10.7 to 11.7 GHz common carrier band.

A suitably biased Impatt diode will, at microwave frequencies, exhibit negative conductance and is thus, basically, a two terminal network which, when used as the termination on a transmission line, will reflect an input signal with amplification. By using the impatt diode on one port of a circulator, the input signal and the amplified reflected output can be separated and the output taken from the third port of the circulator.

The amplifier consists of an impatt diode mounted in a reduced height waveguide cavity into which is built the d.c. bias and microwave matching networks. The amplifier is also provided with a heat sink of suitable size dependent on power output and system mounting. For masthead mounted radio equipment the amplifier will operate over a temperature range of −10 to +50 deg C ambient and maintain an output power in excess of 350 mW at the elevated temperatures expected within the weatherproof enclosure.



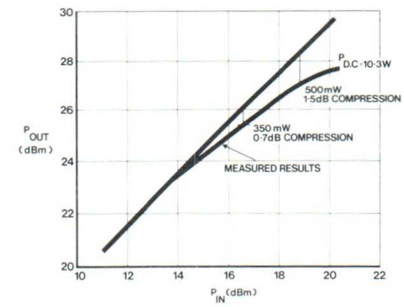
Large signal gain response of negative resistance amplifier

Fig. 2

The performance of the amplifier is as follows:

Centre frequency	11.10 GHz
Bandwidth to 3dB points	± 500 MHz
Bandwidth to 1dB points	± 250 MHz
Saturated gain	7 dB
Power output	Up to 600 mW (dependent upon maximum ambient temperature).
Spurious output	− 60 dB
Input power d.c.	10.3 W 120 mA, 86 V d.c.

The 600 mW amplifier is illustrated in Figure 1 and the large signal gain response curve and a gain compression curve are shown in Figures 2 and 3 respectively.



Compression of negative resistance amplifier

Fig. 3

Fig. 4

EMI-Varian amplifiers are also being developed within the range 8.4 to 12 GHz with power outputs up to 1 W. An example of a higher power single stage amplifier is illustrated in Figure 4. The amplifier operates with an input level of 100 mW and a d.c. input of 22 W. The output power and gain can be adjusted to provide an output of 1 W with a 3dB bandwidth of 400 MHz or an output of 800 mW with a 3dB bandwidth of 1 GHz. This amplifier is also designed to work in an ambient temperature of 50°C.

Erratum 9821B Data Sheet

Your attention is drawn to the electrical characteristics where the QE is given as typically 25% at 280nm. This should be typically 25% QE at 380nm.

EMI

PRODUCT INFORMATION

July, 1974

Dear Sir,

PHOTOMULTIPLIER TUBES

We have recently introduced an important addition to our range of photomultiplier tubes. This 78mm (3 inch) diameter tube type 9821 is a fast linear focused tube with a typical rise time of 2·1ns. There is a provisional data sheet attached; this supplies all the relevant data on this tube which is now commercially available at £130 each plus VAT. Discount for quantities is applicable.

PHOTOMULTIPLIER ACCESSORIES

To ensure that optimum results are obtainable from our photomultiplier tubes, we market a range of precision accessories.

Photomultiplier Power Supply

The power supply type PM25A has been specifically designed for use with photomultiplier tubes, incorporating a time delay which eliminates the danger of switch-on surges that can cause considerable damage to a photomultiplier.

Magnetic Focusing Assemblies

Magnets type C121 or C122 can be used to reduce the dark current in a photomultiplier by up to 95% of the unfocused dark current. The magnetic field produced by the assembly deflects electrons from the edge of the cathode and the side walls away from the dynode system so that they are not multiplied.

Ambient Temperature & Cooled Photomultiplier Housings

A range of housings is available, both ambient temperature and cooled types, all of which are designed for obtaining maximum benefit from your photomultiplier tube system. A full catalogue is available upon request.

Data is enclosed on the new 'fast' tube, Power Supply PM25A, and the magnetic focusing assemblies. Should you require any further information on any of our products, please contact us.

Yours faithfully
EMI ELECTRONICS LIMITED

L.W. Morgan

L.W. MORGAN
Electron Tube Division
Extension 2076

TYPE 9821B

Photomultiplier Tube

PROVISIONAL DATA

CHARACTERISTICS

Mechanical

Maximum envelope diameter		78 mm
Seated height	uncapped: capped	158 ± 3 mm 175 ± 3 mm
Nominal cathode diameter		60 mm
Cathode type		Bialkali (KCs)
Window material		Borosilicate
Dynodes	number: type: secondary emitter:	12 (10 stage available) Linear focused BeO(Cs)
Base		B19A (uncapped) or B20 (capped)

Electrical

Tube Type	QE 280 nm Typ.	Cathode Sensitivity (μA/lm) Min.	Typ.	Corning Blue Min.	Typ.	200 A/lm V.Overall Typ.	Max.	Dark Current nA Typ.	Max.	Overall Sensitivity 2000 A/lm V.Overall Typ.	Dark Current nA Typ.
9821	25%	–	75	7·0	9·5	2050	2500	3	15	2550	30

Anode pulse rise time:	typical maximum	2·1 –	n.sec n.sec
Anode pulse f.w.h.m.:	typical maximum	3·2 –	n.sec n.sec
Electron transit time:	typical	35	n.sec
Operating temperature:	maximum minimum	+ 60 –20	°C °C
Capacitance, anode to all dynodes	uncapped: 4 pF capped:	5	pF
Energy resolution	^{137}Cs, 69 mm x 69 mm crystal NaI-T1 typical	8·0%	

Ratings

Overall sensitivity	rated maximum	200 2000	A/lm A/lm
Cathode to d1 voltage:	recommended maximum	450 600	V V
Cathode to anode voltage	maximum subject to not exceeding	3000 2000	V A/lm
Inter-dynode voltage	maximum	550	V
Anode to last dynode voltage	maximum	550	V
Maximum anode current (mean)		0.2	mA
Maximum anode dissipation		0.1	W
Maximum cathode current (assuming whole cathode used)		0.3	μA

Circuit notes

General notes on the design of dynode chains are given in the introductory article in the EMI photomultiplier catalogue P001/fP70, available on request. Any comments below, however, are relevant to the dynode chain for the particular tube described on this data sheet.

Focus (F) may be connected to D1 for normal operation.
Tube may be gated off by application of −50 volts w.r.t. cathode to this electrode.

Operating notes

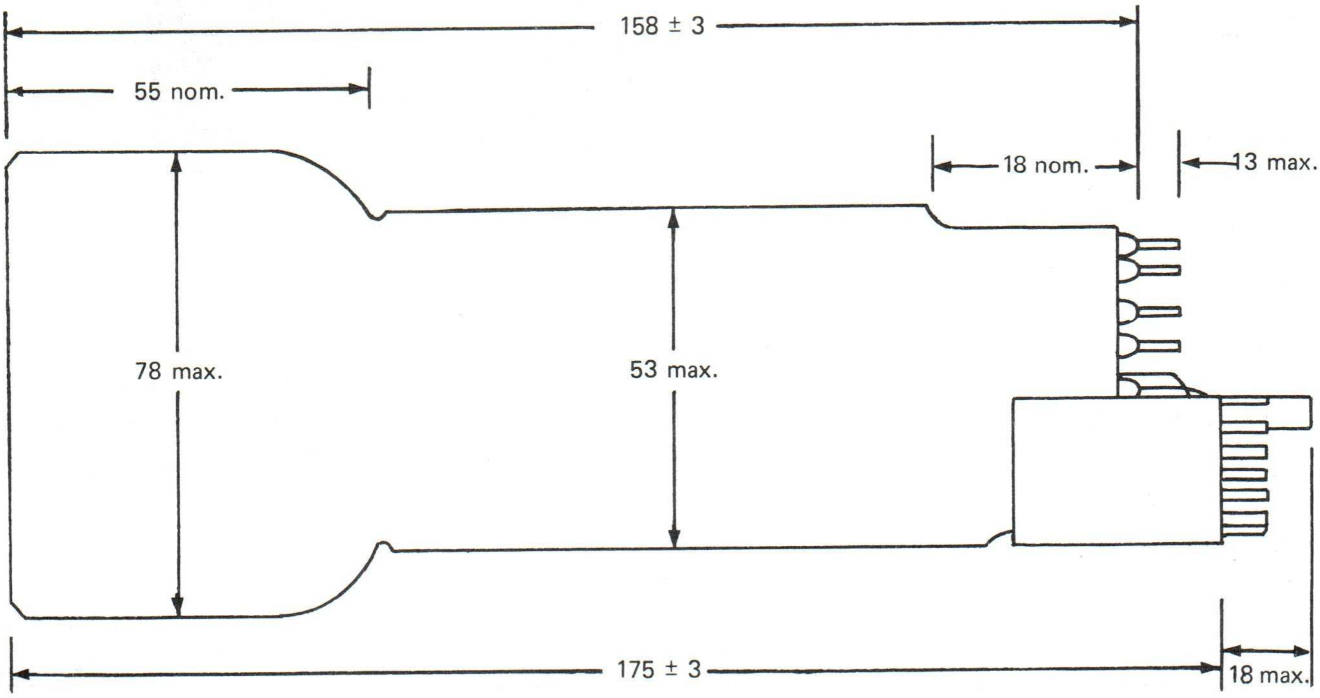
1. Each tube is individually calibrated and supplied with a test ticket giving the cathode sensitivity in μA/lm and/or cathode sensitivity measurements with filters appropriate to the type of photocathode. The overall voltage and dark current (at 20°C) corresponding to the rated overall sensitivity are also given.

When a Corning blue figure is given a Corning glass filter, CS−5−58 ground to half stock thickness, is interposed between the standard source, giving 0·001 lumens at 2857°K, and the photocathode. In the case of red sensitive photocathodes, additional cathode sensitivity figures are given relative to glass filters, types Cs−2−62 and Wratten 87, which pass all radiation of wavelength longer than approximately 600 nm and 800 nm respectively.

2. Generally, tubes should be operated at or near their rated overall sensitivity. Care should be taken not to exceed either the maximum rated sensitivity or the maximum voltage.

3. For optimum stability under dc conditions, the mean anode current should not exceed 1·0 μA.

4. For general notes on the operation of Photomultiplier Tubes see EMI Photomultiplier Supplement catalogue ref P001S/a72, page 1 and the EMI Photomultiplier Catalogue ref P001/fP70, both available on request.



Pin connections. Tube viewed from below counting clockwise from short pin or key.

Pin No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Base Type
Electrode		D1	D1	D3	D5	D7	D9	D11	−	A	D12	D10	D8	D6	D4	D2	−	−	F	K	B20
	−	D1	D1	D3	D5	D7	D9	D11	A	D12	D10	D8	D6	D4	D2	−	−	F	K		B19A

For further information on this product please telephone Extension 2076

EMI

PHOTOMULTIPLIERS ACCESSORIES

MAGNETIC FOCUSING ASSEMBLIES

The EMI magnetic focusing assemblies are designed to provide a reduction of the effective cathode area and a corresponding decrease in the cathode dark current in end window photomultiplier tubes. This results in improvements in the signal/dark current ratio and so in the limit of detection of low intensity light. The two versions available, type C121 and C122, produce effective cathode diameters of approximately 6 mm and 12 mm respectively and are for use with 50 mm diameter venetian blind photomultiplier tubes (including 9684).

The magnetic field produced by the assembly deflects electrons from the edge of the cathode and the side walls away from the dynode system so that they are not multiplied. As a result, a considerable reduction in dark current is achieved.

The magnets can be used successfully where a small diameter incident beam is convenient or where the incident radiation can be focused on to a small area of the photocathode. They are designed for use with thermoelectric and dry ice photomultiplier tube housings manufactured by Products for Research Inc, as well as for custom built assemblies.

Characteristics

			Type C121	Type C122
Outside diameter	max.	mm	51·8	51·8
Depth of assembly	max.	mm	12·0	17·0
Effective cathode dia. (see note 1)	nom.	mm	6·0	12·0
Approx. dark current as a percentage of unfocused dark current (see note 5)			5	20

Notes

1. The effective cathode diameter is the full width at half-maximum amplitude of the anode output as a small spot of light is swept across the cathode.

2. The assembly must be positioned so that the surface which is flush with the outer collar is against the photomultiplier window. It may then be held in place with adhesive tape. Alternatively, when the thermoelectric or dry ice housings, manufactured by Products for Research Inc, are to be used, the assembly should be fitted inside the corrugated pressure sleeve in the housing immediately in front of the photomultiplier window.

3. A mu-metal shield should be used with the magnet for optimum performance and ideally both should be maintained at cathode potential. If this is not possible, the assembly should be left unconnected and should not be earthed if the anode is at earth potential.

4. Care should be exercised when handling these magnets and they should not be stored in close contact with one another.

5. The figures quoted for the 'focused' dark current as a percentage of the 'unfocused' dark current are for a 9558B operated at an overall sensitivity of 200 A/lm. The percentage reduction obtained will vary from tube to tube and will depend on the particular type of photocathode employed.

For further information on this product please telephone Extension 2076.

EMI

EMI Electronics Limited, Electron Tube Division,
243 Blyth Road, HAYES, Middlesex. UB3 1HJ, England.
Telephone: 01–573 3888 Cables: Emitube, London. Telex: London 935261
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P216/B
DS.1115/2

POWER SUPPLY

The Power Supply Type PM25A has been specifically designed for use with photomultiplier tubes and for other applications where a highly stable and compact power unit is required.

The PM25A:

- delivers 100 V to 2500 V at 5 mA max.
- has dual output polarity facility
- has adjustable output voltage resettable within fine limits
- has freedom from switch-on surges
- is compact – 216 mm x 127 mm x 229 mm

The output voltage range covered by this unit is 100 V to 2500 V and is adjustable to give any voltage within this range. This is achieved by means of a 12-way switch which gives voltage changes in 200 V steps. For fine control a 3-turn potentiometer is used which adjusts the volts up to 300 V above the 12-way switch setting; the potentiometer is scaled in 1 V divisions.

Either polarity may be obtained by using one of the two specially wired connectors. Both these connectors have coaxial wire leads attached and are included with the unit. This method of polarity selection considerably reduces the risk of accidental polarity change that could occur if switch selection was used.

The high specification and very economical price have been achieved by the use of hybrid techniques. A stabiliser valve and a time delay are used which eliminate the danger of switch-on surges that can cause considerable damage to a photomultiplier. Except for this valve, solid state components are used throughout to give a compact, reliable unit having good stability with time and temperature variations.

ELECTRICAL SPECIFICATIONS

Output voltage	100 to 2500 V
Polarity	Positive or negative w.r.t. chassis by connection of output socket.
Maximum current	5 mA
Overload protection	Current limit at 6 mA, autoreset. Foldback to approx. 2·5 mA on short circuit. Lamp indicates limiting.
Load regulation	10 ppm from a no load to a full load change.
Line regulation	10 ppm for a 10% change of mains voltage.
Ripple and noise	2 mV peak to peak.
Meter	70 mm (2·75 in.). Scale length accuracy 3%.
Mains supply	200 to 250 V or 100 to 125 V, 48 to 66 Hz. 50 VA @ 240 V rms ac.
Resolution	110 mV (200 volt steps + 3-turn pot.)
Accuracy (with variable control at zero)	1%
Accuracy of fine control	3% of indication.
Temperature coefficient	100 ppm/°C typ.
Drift with time (at constant line, load and temperature)	50 ppm/hr typ. 100 ppm/day typ.
Output voltage float potential w.r.t. chassis (either terminal)	250 V dc max.
Maximum ambient temp.	
Working	45°C
Storage	70°C
Net weight	3·6 Kg (8 lb).
Output connector	Belling Lee L1390 series.
Output lead	UR 70

For further information on this product please telephone Extension 2073.

EMI

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P144/2C
DS.1147

EMI news

from EMI Electronics and Industrial Operations, Blyth Rd., Hayes, Middlesex. Telephone: 01-573 3888

124/73 26th September 1973

FIRST "BRITISH MADE" 18 MM VIDICON TUBE INTRODUCED BY EMI

The Electron Tube Division of EMI Electronics Limited, Blyth Road, Hayes, Middlesex, has introduced an 18 mm ($\frac{2}{3}$") vidicon type 9831.

It is designed to operate in standard 18 mm scan and focus coil assemblies and is primarily intended as a direct replacement in existing compact television cameras.

EMI's new vidicon features a low wattage heater, separate mesh construction and high quality processing of the target layers. This offers better shading characteristics and improved sensitivity. The tubes are produced to very close limits and are individually tested immediately prior to despatching to the customer.

With a $\frac{2}{3}$" magnetically focussed and deflected vidicon the size and weight of the associated scanning assembly can be considerably reduced. The tube is normally associated with industrial cameras, but higher grade versions will be offered for use in broadcast and educational television studio and telecine equipments. Specialized formats will include non-browning faceplate versions for use in fields of nuclear radiation. A version with a fibre optic faceplate for direct coupling to an intensifier, eliminates the need for an intermediary coupling lens, providing a much higher light transmission. An ultra voilet sensitive target layer will be available for use in microscopy and for inspection of items which are surrounded by intense red heat. Because this has negligible dark current, it permits the signal current to be integrated over a period of time and enables the tube to be used for low light scientific purposes.

Date is available on request from Electron Tube Division, EMI Electronics Ltd., 243 Blyth Road, Hayes, Middlesex.

E N D S

Press enquiries:

Patrick Daly - Publicity Executive
Extn: 2764 Home: Cuffley 4222

or

Colin Woodley - Publicity Manager,
Extn: 606 Home: Hemel Hempstead 55128

EMI

PHOTO NEWS

from EMI Electronics and Industrial Operations, Hayes, Middlesex, England. Telephone: 01-573 3888

124/73

Neg.No.464-5

FIRST "BRITISH MADE" 18 MM VIDICON TUBE INTRODUCED BY EMI

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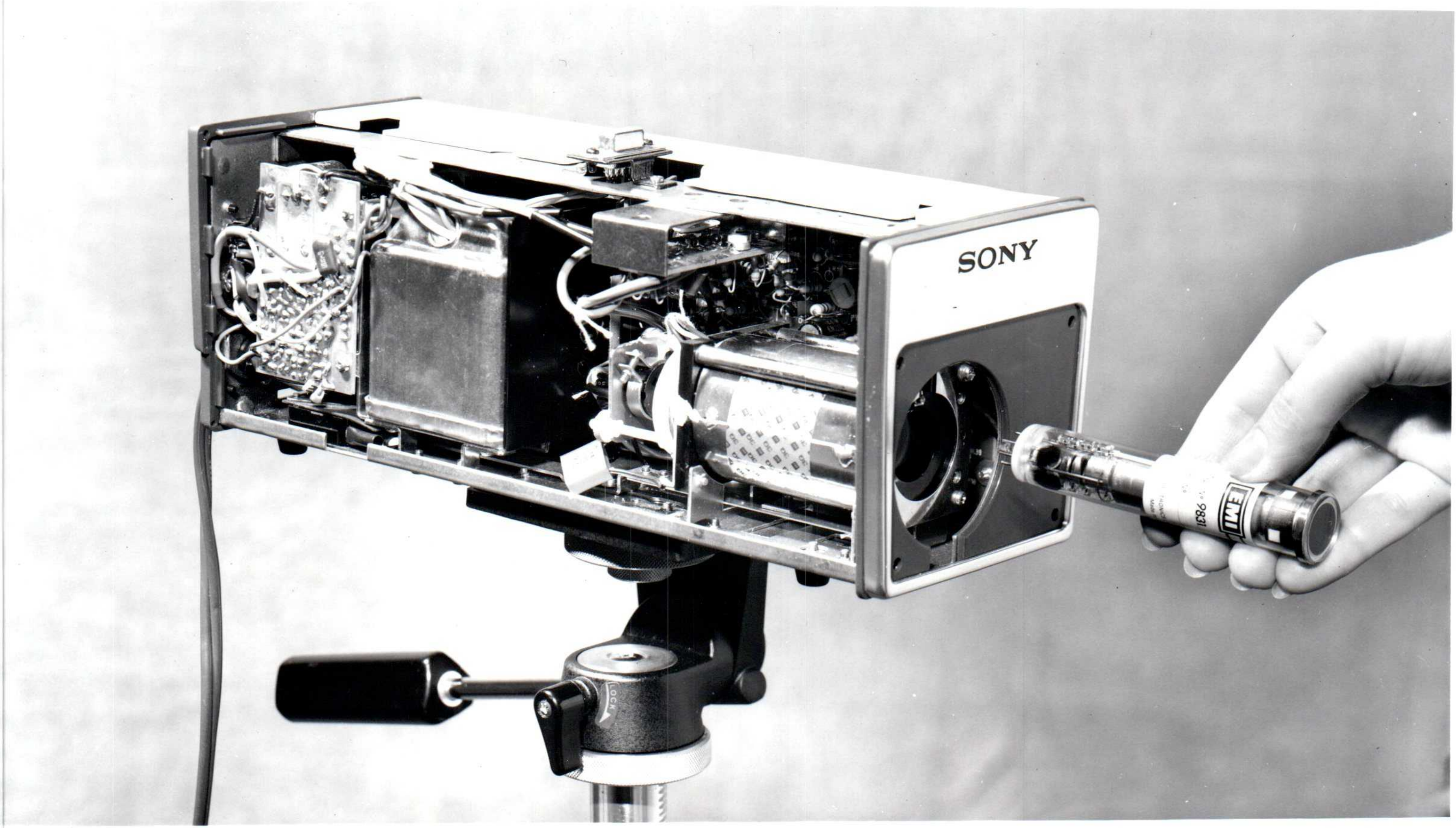
EMI's new vidicon, shown here, features a low wattage heater, separate mesh construction and high quality processing of the target layers.

E N D S

Press enquiries: Patrick Daly - Publicity Executive
Extn: 2764 Home: Cuffley 4222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ALAN HALL PHOTOGRAPHY
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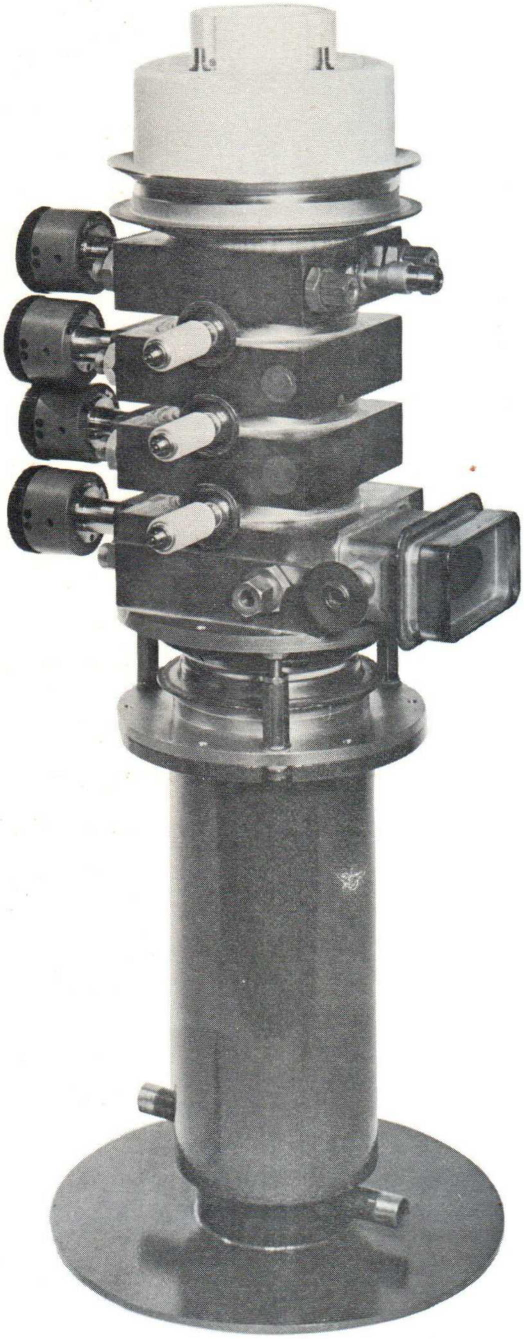
EMI-Varian Ltd

Provisional data sheet

Electrostatically focused klystron PT1016

The PT1016 is a 4 cavity, S-band, liquid cooled, electrostatically focused klystron amplifier basically designed for lightweight applications

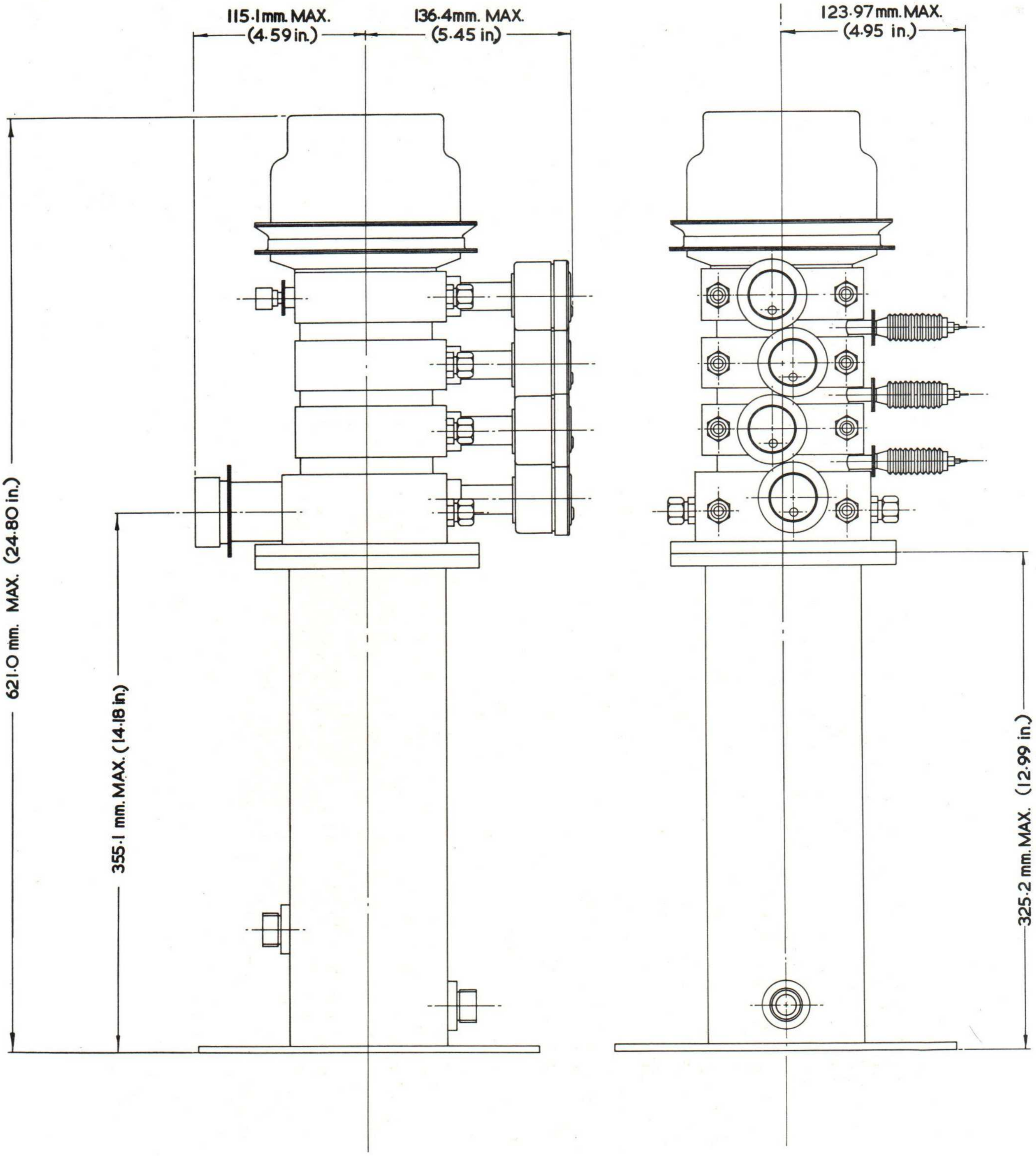


Provisional Specification

Frequency Range – Tunable over 200 MHz within the frequency limits 3000 to 3500 MHz.

	Anode modulated	Cathode modulated
Peak R/F output power	20 KW	30 KW
Mean R/F output power	10 KW	10 KW
Gain	50 dB	50 dB
Beam voltage	27 KV	31 KV
Beam current	2.1 A	2.75 A
Beam perveance	0.5 µP	0.5 µP
P.R.F.	50 kHz	30 kHz
Pulse length	10 µS	10 µS
Attenuation (beam off)	100 dB	100 dB
Efficiency	35%	35%
Heater volts	10 to 12 V	10 to 12 V
Heater current	6 to 7 A	6 to 7 A
Target cooling water	4 gallons (18 litres) per minute minimum.	
Body cooling water	1 gallon (4.5 litres) per minute minimum.	

Water outlet temperature not to exceed 60°C.



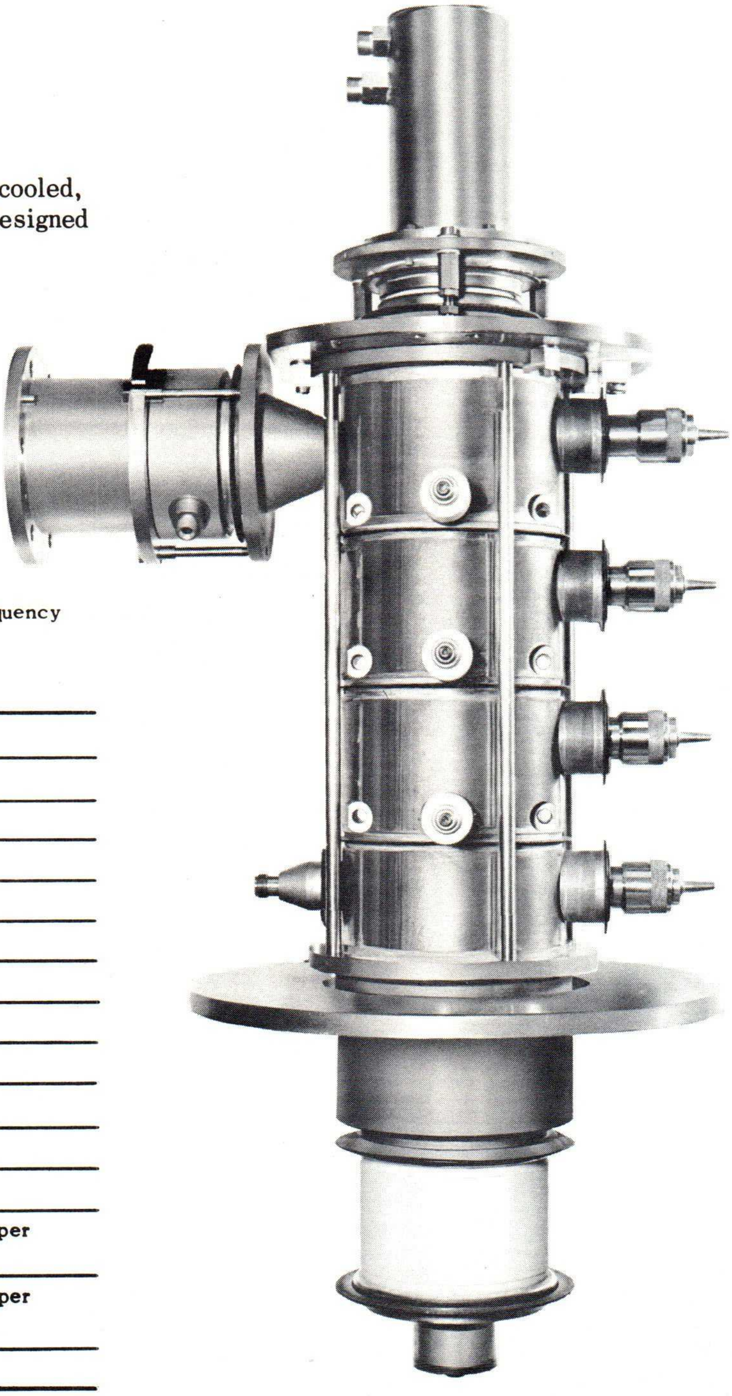
Outline of Klystron Amplifier Type PT1016

DS.940/2

EMI varian

EMI-Varian Ltd

Provisional data sheet



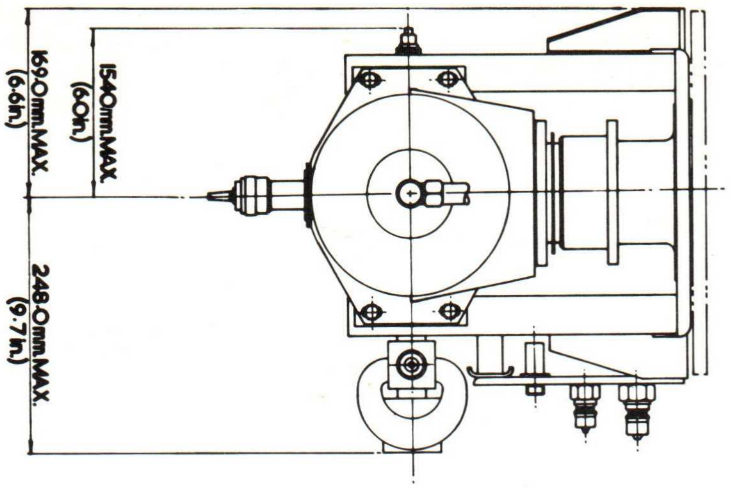
Electrostatically focused Klystron PT1024

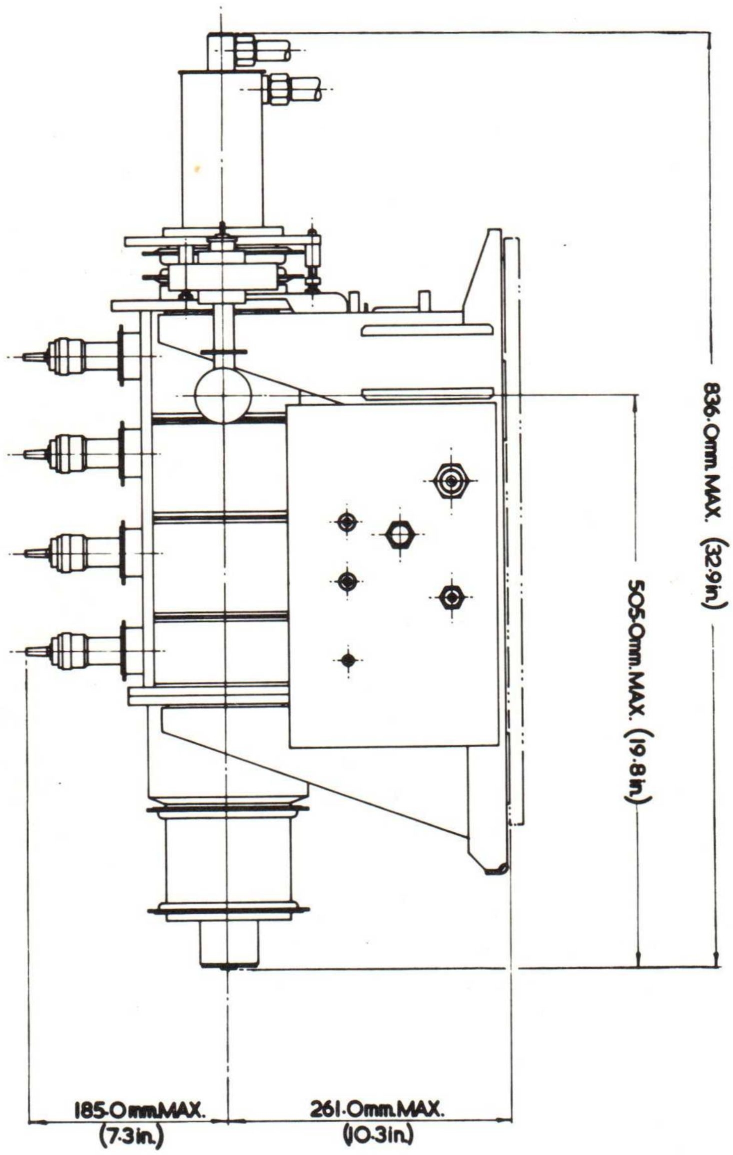
The PT1024 is a cathode-modulated, L-band, water-cooled, electrostatically focused klystron power amplifier designed for lightweight applications.

Provisional Specification

Frequency Range – Tunable over 75 MHz within the frequency limits 1200 to 1400 MHz.

Peak R/F output power		100 kW
Mean R/F output power		6.25 kW
Gain	(maximum)	47 dB
Dynamic bandwidth		5 MHz
Beam voltage	(maximum)	45 kV
Beam current	(maximum)	9 A
Beam perveance		1 μP
P.R.F.	(maximum)	12.5 kHz
Pulse length	(maximum)	10 μS
Efficiency	(minimum)	30%
Heater volts	(nominal)	20 V
Heater current	(nominal)	17 A
Target cooling water	(minimum)	30 litres per minute
Body cooling water	(minimum)	10 litres per minute
Weight		60 kg





Outline of

Klystron Amplifier

Type PT1024

DS.950/2

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