A 2000 WATT CW MIC 20-500 MHz SPDT PIN DIODE SWITCH MODULE

R. TENENHOLTZ
High Power Control Device Division
Microwave Associates
Burlington, Mass. 01803

ABSTRACT

An MIC 0.75 inch diameter VHF/UHF switch module employing packageless diodes has been developed that operates over two octaves in the 20-500 MHz range. It has been tested up to 2.0 KW CW!! This represents a factor of 10 in power greater than previously reported. Several switch assemblies employing this module design are described and test results presented.

INTRODUCTION

Diode switch technology offers the microwave engineer a unique building block enabling him to achieve a high degree of reliable system sophistication. Unlike its earlier counterpart, the mechanical switch, it operates at microsecond or less speeds, and is free of mechanical wear problems. In the VHF/UHF frequency range, recent solid state power amplifier developments have forced a dramatic new requirement; operation up to 1500 W CW.

DISCUSSION

In order to meet this challenge, a PIN diode with documented high reliability performance was selected as the basic switching element. It is a 6 mill I region design with hard glass passivation. Physical size is 0.110 x 0.110 x 0.015 inches and pertinent characteristics are presented in Table I.

TABLE I

HIGH POWER PIN DIODE CHARACTERISTICS

I REGION THICKNESS	6.0 MILLS
BULK BREAKDOWN	1800 V
I REGION DIAMETER	90 MILLS
JUNCTION CAPACITANCE	3.0 pf
TYPICAL BIAS, dc REVERSE FORWARD	 400 V 300 mA
FORWARD RESISTANCE @ 1.0 GHz	0.2 OHMS
CUTOFF FREQUENCY (REVERSE BIAS)	250 GHz
CARRIER LIFETIME @ 10 mA	15 μs
THERMAL RESISTANCE	1.5 °C/W
MINIMUM THERMAL TIME CONSTANT	1700 μs

The basic MIC module employs four of these diodes in a SPDT two pair back to back configuration. The 1800V breakdown characteristic now has an effective 3600V breakdown with regard to RF considerations. In order to insure proper heat sinking under high power conditions, a thick film MIC puck assembly was developed: this consists of a metallized circuit pattern on a beryllium oxide disc measuring 0.750 diameter by 0.075 thick. This in turn is brazed to a 5/16-24 threaded OFHC copper stud. Diode chips and interconnecting straps are soldered to the circuit pattern at the appropriate locations. A complete assembly is shown in Figure (1) and its schematic in Figure (2).

Utilizing two of these modules, a series/shunt SPDT switch was constructed based on the schematic shown in Figure (3). Use of diode pairs enables ease of biasing and supression of even order harmonics. The series shunt configuration provides high isolation characteristics independent of unmatched load conditions that could be encountered. The actual switch is shown in Figure (4) with both modules clearly visible. All high power coils (7) are hidden from view since they are mounted on the "undersurface". Type N connectors are used for both input and output ports.

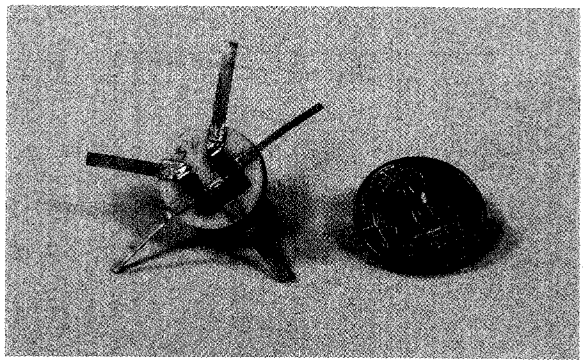

FIGURE 1. HIGH POWER VHF/UHF DIODE SWITCH MODULE

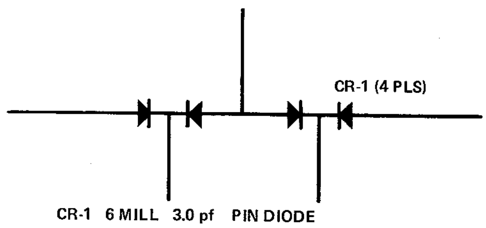

FIGURE 2. HIGH POWER SPDT DIODE MODULE SCHEMATIC

D-20661

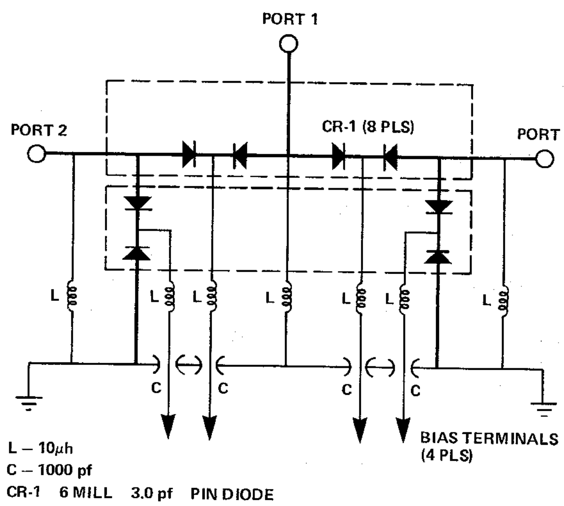

FIGURE 3. HIGH POWER SPDT DIODE SWITCH SCHEMATIC

D-20662

0149-645X/81/0000-0252$00.75 © 1981 IEEE

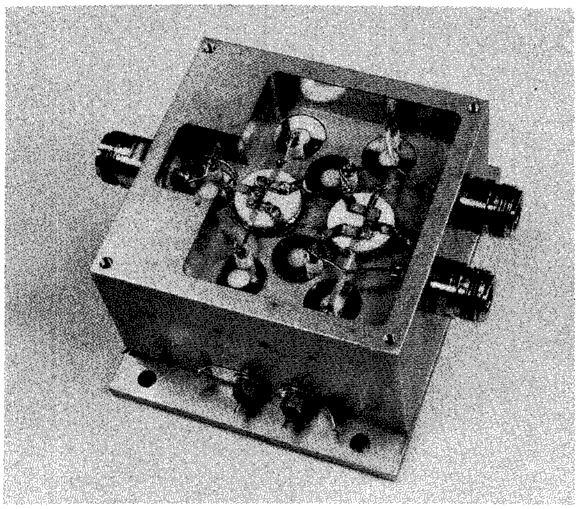

FIGURE 4. HIGH POWER VHF/UHF SWITCH ASSEMBLY EMPLOYING SERIES/SHUNT DIODE MODULES

Low level test data is presented in Figure (5). Insertion loss is extremely low but this is to be expected by virtue of the high Q characteristics of the PIN diodes and RF coils employed. At mid band where reflection loss effects are negligible (RL > 30 dB), insertion loss is 0.08 dB maximum. At the high end of the band, loss increases due to mismatch effects.

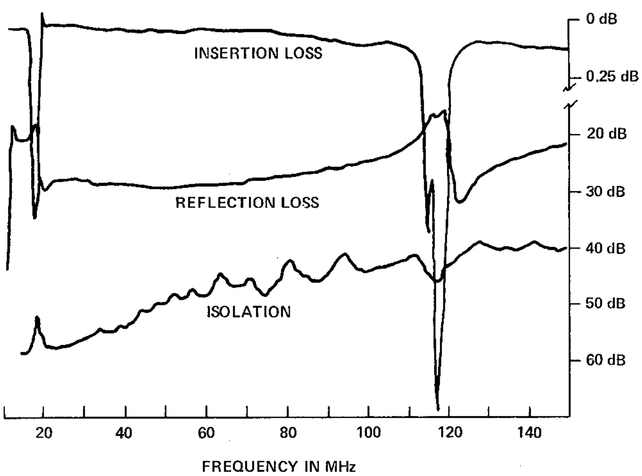

FIGURE 5. LOW LEVEL PERFORMANCE OF HIGH POWER VHF/UHF SWITCH ASSEMBLY

D-20663

As shown, over the greater than two octave bandwidth of 20-100 MHz, excellent performance is achieved. Below this, a deterioration resonance condition can be seen which is caused by the coils, diode capacitance and stray capacitance introducing a shunt series resonant condition. This is effectively controlled by utilizing coils of sufficiently high inductance to force its occurence below the frequency range of interest. This approach is limited by another effect which is the upper band resonance. In this case the coil wire approaches a one half wavelength resonant condition. This clearly illustrates the bandwidth limitations of this type of circuit. The 5:1 coverage can be achieved up to 500 MHz with essentially the same performance show in Figure (5). Only the interconnecting RF lines and bias coils would have to be changed.

After low level RF tests, the SPDT switch assembly shown in Figures (3) and (4) was subjected to high power tests over the 20-100 MHz range. At 1500 W CW, diode junction temperature rise was measured and found to be 30-40° C above ambient temperature which reached a value of 75° C. Convection cooling only was employed. This result appears quite realistic on the basis of a calculated 6° C/watt thermal resistance for the diode puck assembly and a diode series resistance of 0.20 ohms under forward bias. In Table II, a "loss budget" is presented which summarizes the various contributors of dissipation loss. The calculated value of 0.10 dB agrees quite well with the measured value of 0.08 dB.

TABLE II

HIGH POWER VHF/UHF DIODE SWITCH ASSEMBLY LOSS BUDGET

LOSS MECHANISM	POWER DISSIPATED IN WATTS	LOSS VALUE IN dB
SERIES DIODE (0.20 OHMS)	6.0	0.017
SERIES DIODE (0.20 OHMS)	6.0	0.017
SHUNT DIODE PAIR	3.0 (EST.)	0.009
SHUNT DIODE PAIR	3.0 (EST.)	0.009
SHUNT BIAS COILS (X4)	6.0 (EST.)	0.017
RF CIRCUIT LOSS	10.0 (EST.)	0.03
TOTAL	24 W	0.10 dB

BASED ON 1500W CW INPUT POWER LEVEL.

After initial high power tests, a 3:1 VSWR load was employed under various phase conditions to further stress the switch assembly and simulate a worst case operating environment at the 1500 W CW input level. Testing was concluded after a level of 2000 W CW, the limit of the test set up, had been reached. No problems were encountered. During all high power tests 400 V dc and 300 mA dc/diode bias conditions were employed. A ±10% variation in these levels showed no observable deterioration in performance.

In Figure (6) a high power TR switch assembly is shown. This package includes the high power switch, high voltage 400V dc driver circuits, BIT circuits and associates power supplies. The RF portion is essentially the same as previously described. Maximum switching rate capability is 200 Hz. Prime input power is 220V ac at 50 Hz.

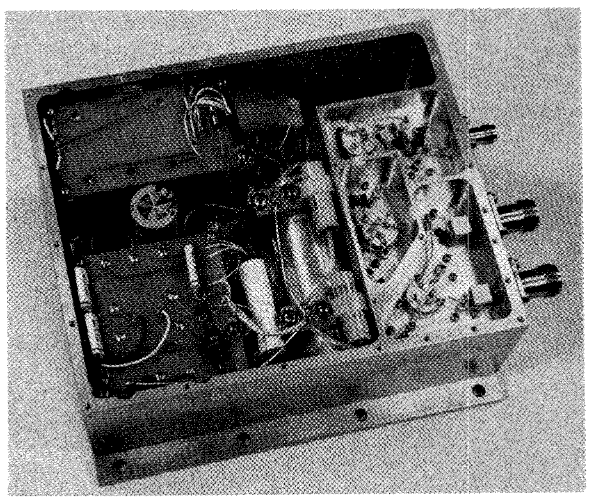

FIGURE 6. MA8306-2W3XD 1500W CW TR DIODE SWITCH/DRIVER ASSEMBLY

A much more complex structure is shown in Figure (7). This too contains a TR switch but in addition two SP4T switches are provided to switch in various filters in the transmitter line. The package also houses all associated 400 V dc driver circuits (10) which are capable of operating at a rate of 6.5 kHz. Prime input power for this design are the required dc levels.

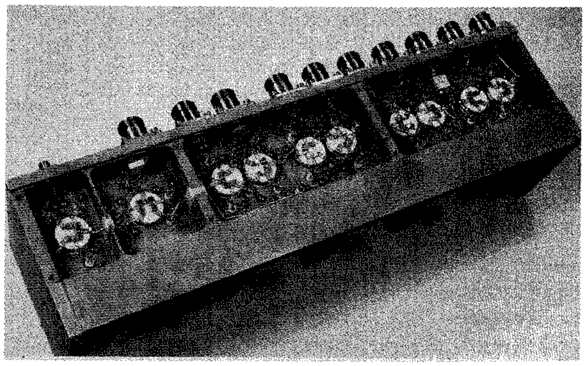

FIGURE 7. MA8306 4WIND 1500W CW TR + 2XSP4T DIODE SWITCH/DRIVER ASSEMBLY

Measured performance of the two assemblies shown in Figures (6) and (7) is presented in Table III along with pertinent electrical and mechanical charactersitics. Both designs are employed in mobile military communication systems.

TABLE III

CHARACTERISTICS OF HIGH POWER VHF DIODE SWITCH/DRIVER ASSEMBLIES

MOD. NO.	MA8306-2W3XD	MA8306-4WIND
CONFIGURATION	SPDT	SPDT + 2XSP4T
FREQUENCY RANGE	20-80 MHz	20-100 MHz
POWER RATING, RF	1500W CW	1500W CW
ANT. TO RCV.	0.25 dB	0.35 dB
TRANS. TO ANT.	0.07 dB	0.15 dB
VSWR		
ANT. TO RCV.	1.15:1	1.25:1
TRANS. TO ANT.	1.10:1	1.30:1
ISOLATION		
TRANS. TO RCV	90 dB	80 dB
SWITCHING SPEED	30 μs	20 μs
MAXIMUM SWITCHING RATE	200 Hz	6.5 kHz
LOGIC INPUT	BALANCED TTL	BALANCED TTL
POWER INPUT	220 V 50 Hz	+ 400 VDC @ 100 mA + 5.0 VDC @ 1.5 A – 6.0 VDC @ 4.0 A
CONNECTORS, RF	SC/TNC	N/SMA
SIZE	9 x 7.9 x 3.5 in.	13.5 x 3.54 x 4.68 in.
WEIGHT	11.5 lb.	12.5 lb.