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Absorption Modulators for Simple or Complex Microwave Modulation

High-performance diode modulators permit microwave modulation by signals ranging from fast waveforms to dc control voltages without frequency reaction

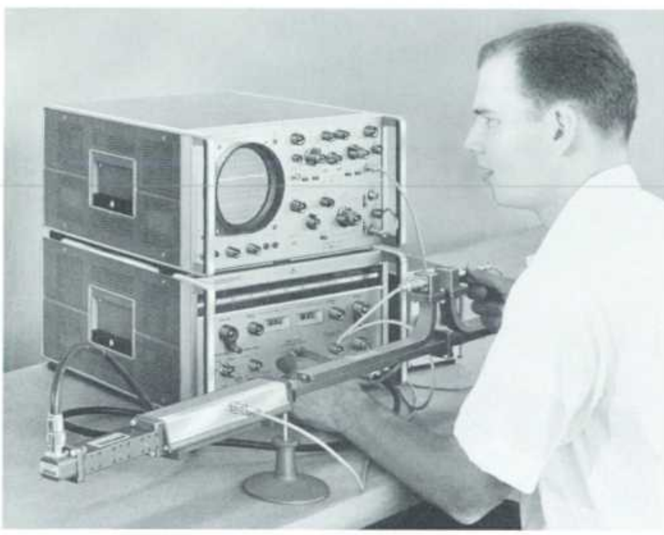

Fig. 1. *Waveguide model of* P-I-N *Modulator can be used on output line beyond coax-to-waveguide adapters or other reflection-producing fittings, and can modulate microwave power with sine waves, complex waveforms, or pulsed signals with extremely fast response. Modulator absorbs microwave power in accordance with instantaneous bias applied to* p-i-n *diodes and is used here to level microwave power in waveguide system.*

(a) *(b)*

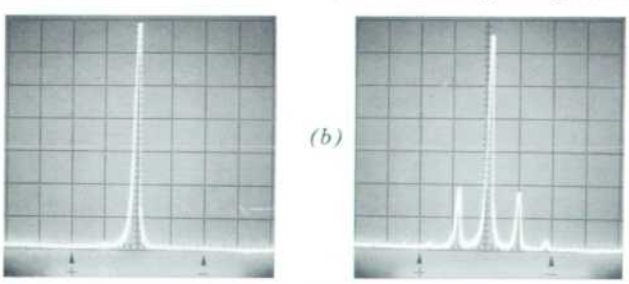

Fig. 2. *Effect of modulation on klystron operation is shown by spectrum of RF in klystron cavity. In photo at left, klystron output is modulated by* P-I-N *Modulator, which shows no visible sidebands. In photo at right, klystron output is modulated by conventional diode switch; sidebands here show frequency pulling. (Modulator pulse rate: 10 kc; spectrum width: 10 kc/cm; vertical scale: linear.)*

AMPLITUDE and pulse modulation of microwave oscillators have always presented certain problems to the microwave engineer because of the undesirable 'moding' and incidental FM that can occur when modulating signals are applied to an element in the microwave tube.

Because of these problems, much interest has been shown in modulation techniques which allow the microwave oscillator itself to operate unmodulated while a diode switch gates the power on the output transmission line. These systems, however, have required isolators or pads to prevent the frequency 'pulling' that is caused in tightly-coupled oscillators by reflections from the switch.

These limitations are circumvented by modulation methods which absorb power on the transmission path. This technique not only allows the oscillator to operate continuously with fixed electrode voltages, but it also reduces reflections below levels that cause frequency pulling. In recent years, this kind of performance has been achieved by ferrite modulators. The response time of these devices, however, has been limited by the switching time of the magnetic field that controls power absorption.

More recently, *p-i-n* diodes have demonstrated[1] a capability for the kind of perform-

[1] J. K. Hunton and A. G. Ryals, "Microwave Variable Attenuators and Modulators Using P-I-N Diodes," IRE PGMTT Transactions, Vol. 10, No. 4, July, 1962.

SEE ALSO:
Microwave signal sources, p. 8

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Fig. 3. P-I-N *Modulators are symmetrical devices that accept RF at either end and supply modulated RF at opposite end. Modulating waveform is applied to BNC connector on side.*

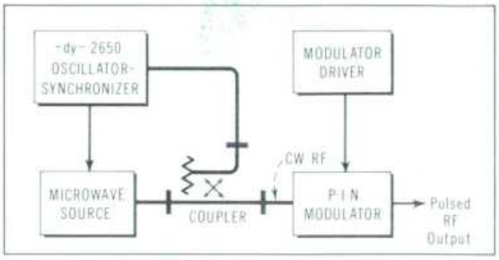

Fig. 4. *Highly stable pulsed RF is generated by CW oscillator phase-locked to frequency reference prior to modulation.*

ance desired. When placed in shunt across a transmission line, these devices behave as electrically-controllable resistances at microwave frequencies and absorb microwave power in proportion to the bias current supplied. This property enables *p-i-n* diodes to serve as variable attenuators for modulating microwave power.

Modulators that use *p-i-n* diodes are compact, lightweight units that have as much as 80-db maximum/minimum attenuation ratios and response times of typically 30 nsec. These capabilities show great potential and have already led to several interesting applications, to be described later in this article.

NEW MODULATORS

Several new *P-I-N* Modulators have recently been designed in two series, an "A" series having a maximum attenuation of 35 db and a "B" series having a maximum of 80 db. The collective frequency coverage of either series is from 0.8 to 12.4 Gc (see Table I).

The new *P-I-N* Modulators are three-port devices with two of the ports serving as input and output for the microwave power while the modulating signal is applied to the third port (Fig. 3). Up to 1 watt of RF power passing through can be modulated by any applied waveform with frequencies up to 10 Mc, or the RF power can be pulsed with rise and fall times of typically 30 nsec.

The *P-I-N* Modulator consists of diodes installed in a section of transmission-line or waveguide without biasing or control circuitry. This allows placement of the *P-I-N* Modulator at any convenient point along the transmission path within a system irrespective of the location of controlling circuitry.

Driving electronics, for those applications requiring it, have been designed into a separate unit. The Modulator-driver provides frequency compensation to extend the *P-I-N* Modulator frequency response to 10 Mc. It also has dc-coupled circuits to permit its use as the control element in microwave power leveling or in other applications requiring controlled attenuation levels.

The Modulator-driver is particularly useful for pulse and square wave applications requiring low pulse jitter and fast rise and fall times. The unit either generates pulses of suitable width and repetition rate itself, or it processes externally-derived pulses to shape them for obtaining maximum rise time when driving any of the *P-I-N* Modulators.

Space is provided within the Modulator-driver enclosure for installation of the diode assembly when an all-in-one modulator is preferred for bench or field work.

APPLICATIONS

The new Modulators are capable of amplitude modulation under the control of almost any time-varying signal. When a typical modulator was driven by a 300-ohm CW voltage source to a modulation depth

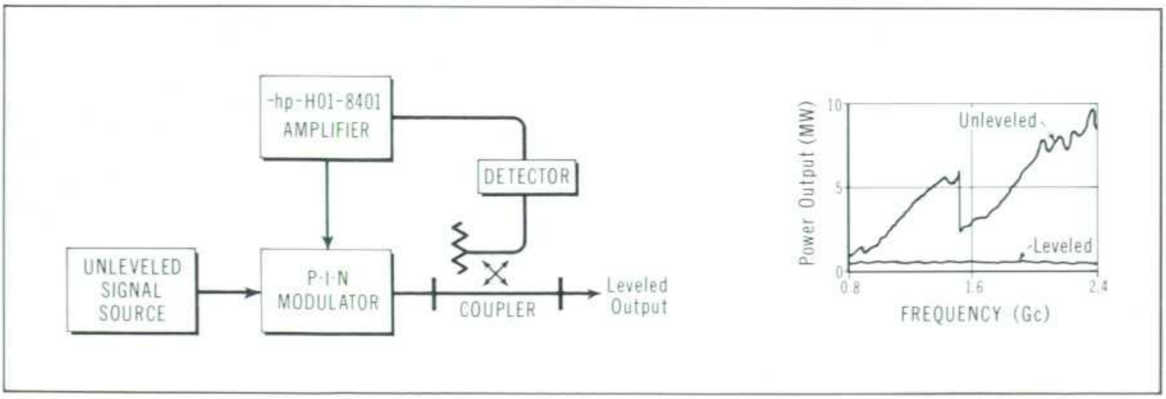

Fig. 5. *Microwave power is leveled by modulator at any chosen point in system.*

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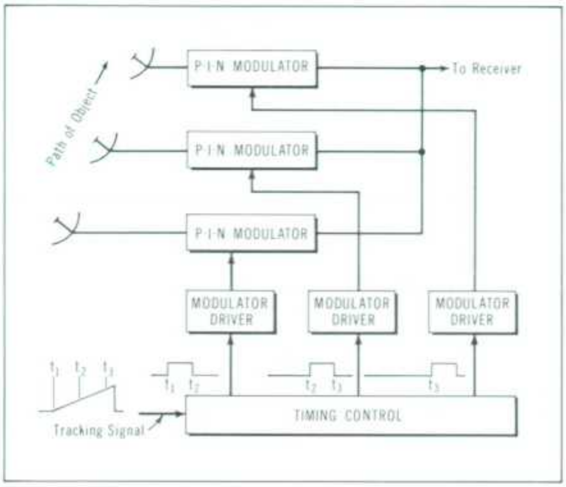

Fig. 6. P-I-N *Modulators are useful for switching antennas sequentially to receiver input, as shown in this high-speed tracking system.*

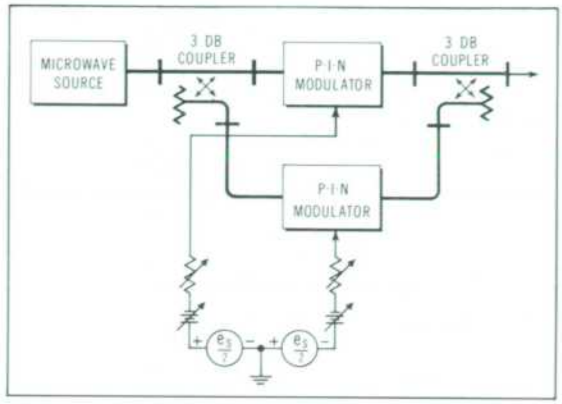

Fig. 7. *Two* P-I-N *Modulators function as balanced modulator by introduction of 180° phase-shift at carrier frequency in one of two parallel RF paths.*

of approximately 50%, the RF envelope was found to have a half power point at a modulating frequency of 1 Mc. Compensated driving circuitry can be designed to provide flat response to 10 Mc or more.

Modulating about a level approximately 7 db down results in less than 5% envelope distortion for modulation depths approaching 60%. Depending upon the degree of linearity and frequency response required, shaping circuits can be incorporated to compensate for the typical transfer curves shown in Fig. 17.

The versatility of the new family of *P-I-N* Modulators adapts them to a variety of applications. For instance, the Modulators can be used in applications requiring pulsed signals that are phase-locked for frequency stability. For this application, the oscillator tube operates CW and the signal is modulated beyond the point where an RF sample is taken for the oscillator-synchronizer, as shown in Fig. 4.

Leveling of microwave power to within a fraction of a db over a 2:1 bandwidth is possible with a *P-I-N* Modulator, a flat detector, and a suitable amplifier, as shown in Fig. 5. Flatness of leveling is limited almost entirely by the coupler and detector, and can be improved by use of the compensated coupler technique.*

The high on/off ratios available in the "B" series Modulators make them ideal for use as SPST switches. One application is the tracking of fast moving objects by switching an array of antennas in sequence, as shown in Fig. 6. Since tracking is done electrically, the mechanical inertia of a single tracking antenna poses no problem.

* "Leveled Swept-Frequency Measurements with Oscilloscope Display" –hp– Application Note No. 61.

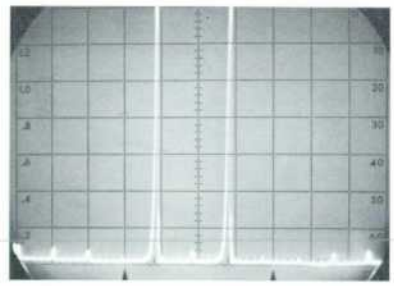

Fig. 8. *Output spectrum of balanced modulator shown in Fig. 7. (Carrier frequency: 2200 Mc; spectrum width: 100 kc/cm; vertical scale: linear.)*

Unlimited possibilities exist when two or more modulators are used in a microwave system. For example, suppressed carrier modulation is obtained with a balanced modulator using two 3-db couplers and two Modulators, as shown in Fig. 7. A 90° phase shift is introduced by each coupler in one RF path and when this signal is added to the signal from the other path, carrier cancellation takes place.

TABLE I

***–hp– P-I-N* MODULATORS**

Basic Model Number	Attainable on/off ratio (db)		Frequency Range (Gc)	Connectors
	"A" Series	"B" Series		
8731	35	80	0.8 - 2.4	Coaxial
8732	35	80	1.8 - 4.5	Coaxial
8733	35	80	3.7 - 8.3	Coaxial
8734	35	80	7.0 - 12.4	Coaxial
X8735	35	80	8.2 - 12.4	Waveguide

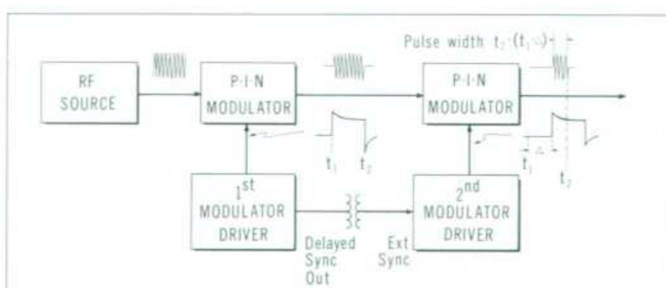

Fig. 9. *Two* P-I-N *Modulators in series achieve short-pulse widths by overlapping pulse "on" times.*

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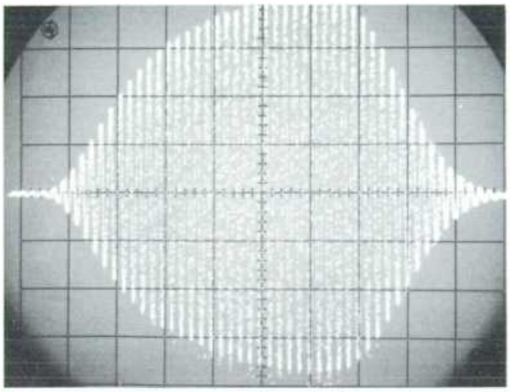

Fig. 10. *Short RF pulse achieved with tandem modulator shown in Fig. 9. RF carrier: 1000 Mc; sweep rate: 5 nsec/cm. Phase coherent pulse is obtained by using RF carrier as sync input to sampling oscilloscope; counted-down sync from scope then triggers first modulating pulse generator.*

In the balanced modulator, the two series resistors are chosen to equalize the sensitivities of the *P-I-N* Modulators, as discussed on page 6, and dc bias voltages are set to provide approximately 7 db of attenuation. The carrier suppression obtainable is shown by the spectrogram of Fig. 8; the low level of additional side bands in the spectrogram gives some indication of the low distortion.

Extremely narrow pulses can be generated by two modulators in series. A single *P-I-N* Modulator driven by the Modulator-driver is limited to 100-ns pulse widths because of internal recovery times in the driver. This limitation is overcome in the set-up of Fig. 9, which passes RF power only when both modulators are "on." The leading edge of the RF pulse therefore occurs when the second Modulator turns on and trailing edge occurs when the first Modulator turns off. Pulse width is determined both by the width setting of the first Modulator and the delay setting of the second. The repetition rate and pulse delay of the composite signal can be varied by the controls of the first Modulator.

A special Modulator-driver used in the generation of simulated DME-TACAN and ATC signals further demonstrates the flexibility of *p-i-n* modulation.

A DME signal consists of gaussian pulse pairs. The requirements on the Modulator system are to provide an RF envelope gaussian over at least the top 20 db of the pulse and to attenuate the RF at least 80 db between pulses. TACAN signals are generated by superimposing a low frequency sinusoid on the DME pulse peaks to a depth corresponding to about 50% modulation. The steps in generating this signal with *P-I-N* Modulators are depicted in Fig. 11.

A three-pulse ATC signal is pictured in Fig. 12. One "A" type and one "B" type modulator are required for the generation of this signal. An additional switching circuit (suppressor) generates the driving signal for the "A" Modulator while the "B" Modulator is driven by the standard driver circuitry in the external pulse mode of operation.*

PRINCIPLE OF OPERATION

The *P-I-N* Modulator consists of a number of *p-i-n* silicon diodes mounted as shunt elements between the center conductor of a strip transmission line and ground (or in ridged waveguide in the higher frequency units). Charge storage in

* The circuitry described above has been designed into a special Modulator-driver, designated as the -hp- Model HO1-8403A.

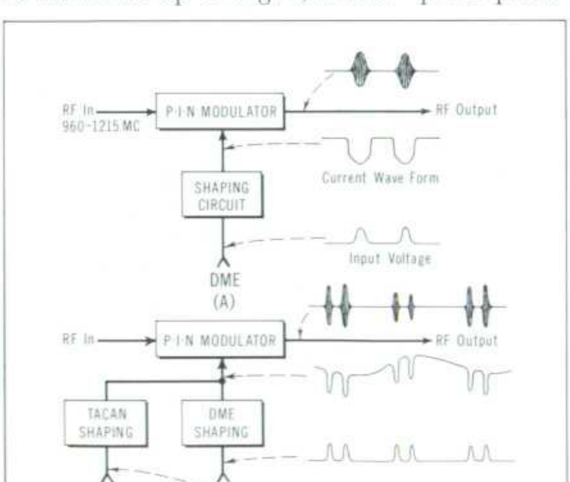

Fig. 11. *DME-TACAN Modulator superimposes TACAN sinusoid on DME pulse pairs.*

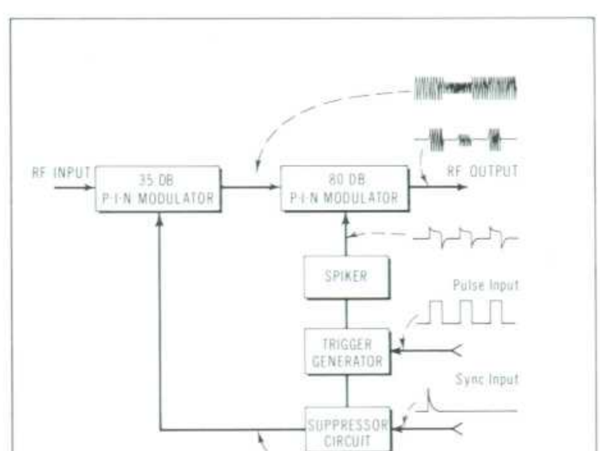

Fig. 12. *Tandem modulators achieve 3-pulse Air Traffic Control operation by using 35-db modulator (8731A) to reduce power into switching modulator (80-db) during center portion of pulse triplet.*

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Fig. 13. *Family of* P-I-N *Modulators includes one pair in each frequency range. "A" model of each pair has maximum attenuation range of 35 db, useful for leveling or for amplitude modulation; "B" model has attenuation range of 80 db for pulse or other "on-off" modulation (see Table I).*

the intrinsic *(I)* layer between the *P* and *N* regions enables these diodes to conduct current in both directions at frequencies above 100 Mc and thus to act as resistances. The equivalent resistance has an ohmic value inversely proportional to the amount of charge in the *I* layer. Varying the dc bias current then varies the stored charge and thus the effective resistance that these diodes present to microwave signals.

To obtain a large attenuation range, several diodes are placed along the transmission line. To optimize VSWR, the diodes are spaced at quarter wavelength intervals in order of increasing attenuation towards the center of the Modulator. This provides an attenuation characteristic that is tapered with respect to distance along the line.[2, 3] The dimensions of the posts on which the diodes are mounted and the dimensions of the strip line adjacent to each diode are chosen to compensate for the reactances of the structure. A schematic representation is given in Fig. 14, which also shows the series resistors that balance the bias current fed to each diode.

High pass filters are an integral part of the device and prevent the modulating signals from appearing directly on the transmission line. The higher frequency units for C and X band use ridged waveguide and depend on the waveguide itself for high pass filtering. RF leakage out the third port is minimized by a low-pass filter.

VSWR

One of the primary advantages of the *P-I-N* Modulators is the excellent impedance match that it presents to the transmission line at all levels of attenuation over a nearly 3:1 RF frequency range. The VSWR of the Model 8731B is shown in Fig. 15 under both zero bias and maximum forward bias conditions.

The advantage of the low VSWR obtained by the absorption type modulator is shown pictorially in Fig. 2. These photos were made with a spectrum analyzer that was connected to a probe in the cavity of a klystron oscillator and thus show the effect on klystron performance of any impedance change at a second probe in the cavity. The left photo shows the spectrum of the klystron while the power out of the second probe was square-wave modulated by the *P-I-N* Modulator. No disturbance to the CW operation of the klystron is evident. Fig. 2b shows the spectrum when a simple diode switch modulator is used. Sidebands, which indicate frequency pulling of the klystron by reflections, are clearly evident.

INSERTION LOSS

The minimum insertion loss of the *P-I-N* Modulators is quite low, making it practical to use two or more *P-I-N* Modulators in series for generation of complex waveforms. A composite plot of the minimum loss from 0.8 to 12.4 Gc is plotted in Fig. 16. For clarity, fine grain variations have been

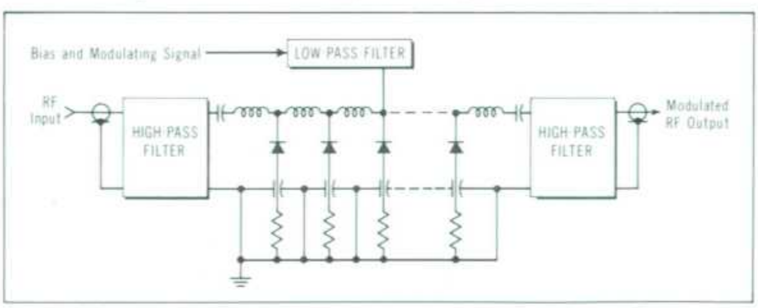

Fig. 14. *Schematic representation of* P-I-N *Modulator. Resistors in series with diodes control diode currents to achieve tapered attenuation characteristic.*

[2] Nicholas J. Kuhn, "A New Microwave Modulator," **Hewlett-Packard Journal**, Vol. 14, No. 7-8, Mar.-Apr., 1963.
[3] Douglas A. Gray, "Design of P-I-N Control Devices," **Microwaves**, Vol. 3, No. 11, Nov. 1964.

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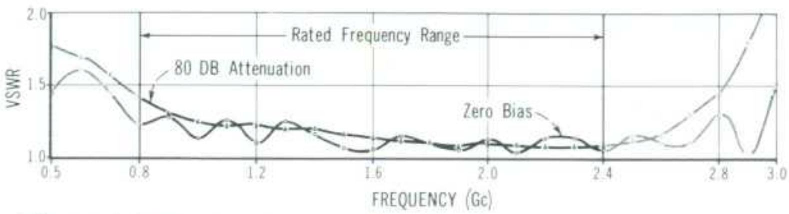

Fig. 15. *VSWR of typical* P-I-N *Modulator (8731B) while biased for full 80-db attenuation and also while biased for minimum attenuation (zero bias).*

smoothed, but the plots show the maximum insertion loss that normally is encountered.

In pulse and square-wave applications, it is recommended that a back bias of about 5 volts be applied during the RF "on" time. In the higher frequency modulators, this results in as much as 1-db improvement in insertion loss over zero bias.

The insertion loss increases with forward bias current almost linearly in db until diode saturation occurs. The attenuation sensitivity varies somewhat from modulator to modulator but any two *P-I-N* Modulators may be made to have comparable sensitivities in db per volt by the simple addition of appropriate series resistance. The range of expected sensitivities is shown as the shaded areas in the plots of typical 35 db and 80 db modulation characteristics in Fig. 17.

The attenuation with forward bias is also a function of diode spacing and hence of frequency. This variation is more noticeable at higher values of attenuation. An 80-db attenuator might have 2 to 5 db variation across the band at the 25-db level. At the 80-db attenuation level the variation might increase another 5 db. Maximum attenuation generally is expected at the center frequency of a particular modulator.

TEMPERATURE EFFECTS

As pointed out in an earlier paper*, the *p-i-n* diode has a small positive temperature coefficient when driven by a voltage source but a negative coefficient when driven by a current source. This suggests that temperature sensitivity can be compensated for at one attenuation level by proper choice of the source impedance. Temperature stability

* See footnote reference 1, page 1.

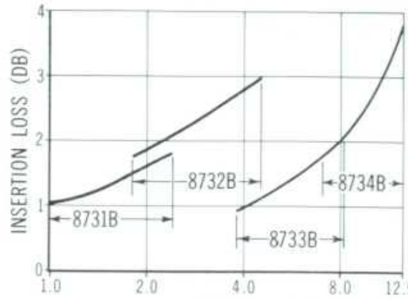

Fig. 16. *Insertion loss of "B" series (80-db) Modulators when back-biased with 5 volts for minimum pulsed RF attenuation.*

can also be achieved by use of a temperature sensitive element in the bias source.

MODULATOR ELECTRONICS

The modulator-driver that has been designed for the *P-I-N* Modulator lines is identical to the electronic portion of the earlier Model 8714A Modulator† except for the inclusion of two outputs (Fig. 18). One output drives the *P-I-N* Modulator directly and provides suitable compensation for waveforms or pulses to obtain wideband response. Pulses, for instance, are spiked to sweep the stored charge into or out of the diodes quickly and thus obtain extremely fast, jitter-free RF pulses with RF rise times running from 15 to 40 nsec

† See footnote reference 2 on page 5.

SPECIFICATIONS
–*hp*– SERIES 8730 *P-I-N* MODULATORS

Model number	8731A	8731B	8732A	8732B	8733A	8733B	8734A	8734B	X8735A	X8735B
Frequency Range (Gc)	0.8-2.4	0.8-2.4	1.8-4.5	1.8-4.5	3.7-8.3	3.7-8.3	7.0-12.4	7.0-12.4	8.2-12.4	8.2-12.4
Dynamic Range (db)	35	80	35	80	35	80	35	80	35	80
Min. Insertion Loss (db)[1]	<1.5	<2.0	<2.0	<3.5[2]	<2.0	<3.0	<4.0	<5.0	<4.0	<5.0
Typical Rise Time (nsec)[3]	40	30	40	30	30	30	30	30	30	30
Typical Decay Time (nsec)[3]	30	20	30	20	20	20	20	20	20	20
SWR, Minimum Attenuation	1.5	1.6	1.5	1.6[4]	1.8	2.0	1.8	2.0	1.7	1.9
SWR, Maximum Attenuation	1.8	2.0	1.8	2.0	2.0	2.2	2.0	2.2	2.0	2.2
Maximum Input Power, Peak or CW (watts)	1	1	1	1	1	1	1	1	1	1
Bias Limits (volts)[5]	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10	+20, −10
Typical Forward Bias Input Resistance (ohms)[6]	300	100	300	100	300	100	300	100	300	100
RF Connector Type	N	N	N	N	N	N	N	N	Wave-guide[7]	Wave-guide[7]
Price	$300.00	$500.00	$300.00	$500.00	$300.00	$500.00	$300.00	$500.00	$300.00	$500.00

1. +5 v bias
2. To 4.0 Gc; 4.0 db to 4.5 Gc
3. Driven by –hp– 8403A Modulator
4. To 4.0 Gc; 2.0 to 4.5 Gc
5. Negative voltage applies forward bias to diodes
6. At attenuation levels of 10 db or more
7. Fits 1 x ½ in. (WR 90) waveguide

Prices f.o.b. factory.
Data subject to change without notice.

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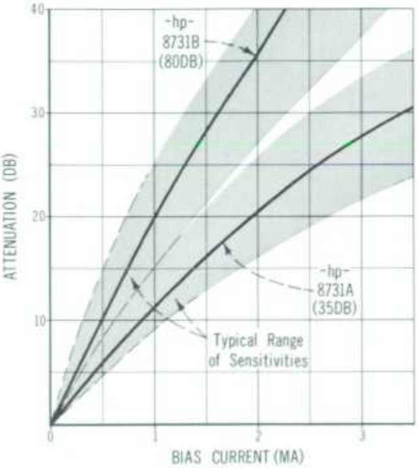


Fig. 17. *Sensitivities of typical modulators plotted as attenuation in db per milliamp of forward bias current. Shaded areas show ranges of expected sensitivities in production instruments.*

and decay times generally less than 20 nsec. The absorption modulator side-steps the risetime limitations imposed by high-Q cavities when a microwave oscillator is pulsed directly.

The other output is driven by the internal pulse generator without special shaping. This output is a 25-30 volt rectangular pulse train which is useful for triggering or gating other circuits in the system.

Fig. 18. *Modulator electronics supplies "pre-emphasized" signal for driving* P-I-N *Modulators. This instrument generates square waves or pulses with controllable width, rate, and sync delay, or it processes externally-derived signals for use with the* P-I-N *Modulators.*

ACKNOWLEDGMENT

The author is indebted to the people who participated in the development of the *P-I-N* Modulators and the associated equipment described in this paper. Those instrumental in the development of the *P-I-N* lines were William J. Benham, Wayne A. Fleming, William W. Nelson and Yozo Satoda. Thomas Lauhon performed the industrial design. Thanks must also be given to –hp– ASSOCIATES for their work on the *p-i-n* diode, in particular to Horace Overacker.

—Douglas A. Gray

DESIGN LEADER

Douglas A. Gray

Doug Gray joined the Microwave Division of Hewlett-Packard in 1960 after attending Polytechnic Institute of Brooklyn and receiving the BEE degree. At –hp– he entered the –hp– Honors Cooperative Program, under which he obtained a MSEE from Stanford University in 1962. In the Microwave Division he has participated in the development of several instruments and is presently project supervisor in charge of high-frequency signal generators and modulators.

SPECIFICATIONS
–hp– MODEL 8403A MODULATOR

OUTPUT CHARACTERISTICS

AM and pulse output for driving 8730 PIN Modulators. Pulse output specially shaped for optimum RF rise and decay times.

Pulse output for general pulse applications. 25 to 30 volts amplitude.

Pulse output signals available concurrently from separate front-panel connectors.

INTERNAL MODULATION

SQUARE WAVE:
- FREQUENCY: Continuously variable from 50 cps to 50 kc, 3 decade ranges.
- SYMMETRY: Better than 45/55%.

PULSE:
- REPETITION RATE: Continuously variable from 50 cps to 50 kc, 3 decade ranges.
- DELAY: Continuously variable from 0.1 μsec to 100 μsec, in 3 decade ranges, between "sync out" pulse and "RF output" pulse.
- WIDTH: Continuously variable from 0.1 μsec to 100 μsec in 3 decade ranges.
- MAXIMUM DUTY CYCLE: See graph.

EXTERNAL SYNC:
- AMPLITUDE: 5 volts to 15 volts peak.
- WAVEFORM: Pulse or sine wave.
- POLARITY: Either positive or negative.
- INPUT IMPEDANCE: Approx. 2000 ohms, dc coupled.
- RATE: Subject to internal recovery time considerations; see graph.

TRIGGER OUT:
- SYNC OUT: 0.1 to 100 μsec in advance of output pulse, as set by DELAY control.
- DELAYED SYNC OUT: Simultaneous with output pulse.
- AMPLITUDE: Approximately −2.0 volts.
- SOURCE IMPEDANCE: Approximately 330 ohms.

EXTERNAL MODULATION

PULSE INPUT:
- AMPLITUDE and POLARITY: 5 volts to 15 volts peak, either positive or negative.
- REPETITION RATE: Maximum average PRF, 1 Mc/sec. Maximum peak PRF, 2 Mc/sec.
- INPUT IMPEDANCE: Approx. 2000 ohms, dc coupled.
- MINIMUM WIDTH: 0.1 μsec.
- MAXIMUM WIDTH: $\frac{1}{PRF} - 0.4$ μsec.

CONTINUOUS AMPLITUDE MODULATION:
- MAXIMUM FREQUENCY: 10 Mc, sinusoidal.
- SENSITIVITY: Approximately 10 db/volt with –hp– 8730A series, approximately 20 db/volt with –hp– 8730B series.
- INPUT IMPEDANCE: Approximately 1000 ohms.
- LEVEL CONTROL: AM input is dc coupled, permitting control by bias of AM input; rear panel control for use with ac coupled modulation.

GENERAL

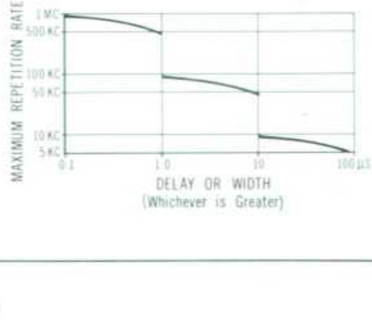
POWER REQUIREMENTS: 115 or 230 volts ±10%, 50 to 1000 cps, approximately 10 watts.

DIMENSIONS: Nominally 16¾ in. wide, 3½ in. high, 16⅜ in. deep behind front panel.

WEIGHT: Net, 14½ lbs. (6,5 kg).

PRICE: –hp– Model 8403A, $700.00.

Prices f.o.b. factory.
Data subject to change without notice.



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NEW MICROWAVE SIGNAL SOURCES WITH SIGNAL GENERATOR CAPABILITIES

Fig. 1. *Operator-oriented Hewlett-Packard Model 8614B Signal Source has push-buttons to quickly select function. Thumbwheel to left of attenuator readout enables any number to be set on attenuator readout, irrespective of actual attenuator setting. Model 8616B is mechanically identical to 8614B but covers frequencies from 1800 to 4500 Mc.*

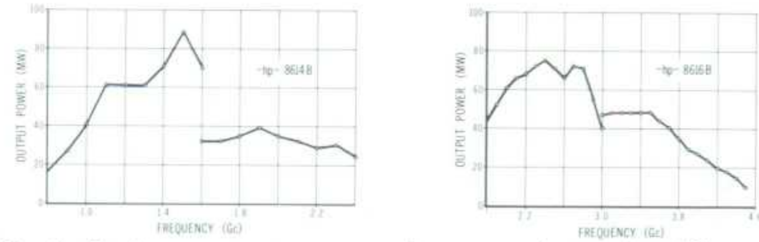

Fig. 3. *Maximum output power vs. frequency of new –hp– Microwave Signal Sources (attenuator probe was adjusted for peak power before each measurement).*

SIGNAL generators, by definition, provide output signals of known power level as well as known frequency. Yet, many microwave measurement set-ups include power meters at some point in the system and do not require that the signal generator be capable of metering its own output power. Microwave power for these applications can just as readily be supplied by "signal sources," i.e., generators which omit the circuitry required for monitoring and calibrating power.

With this concept in mind, two new microwave signal sources have been designed. Each of the new sources has an adjustable output attenuator that is calibrated in relative, but not absolute, levels and can thus often be used in applications that ordinarily would require a signal generator. The attenuator is connected to a digital readout by means of a friction clutch that allows the readout to be set to any convenient reference point.

The new Signal Sources collectively cover a frequency range from 800 to 4500 Mc in overlapping bands, from 800 to 2400 Mc in the –hp– Model 8614B and from 1800 to 4500 Mc in the Model 8616B. Maximum output power through the main RF output is at least 15 milliwatts (3 milliwatts in the higher frequency instrument) and over most of the band, 20 milliwatts is available, as shown in Fig. 3. An auxiliary output, useful for power level monitoring or phase locking the klystron, provides a fixed amount of RF power which is at least ½ milliwatt at the low power point.

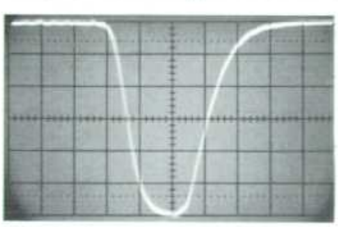

Fig. 2. *Pulsed output of new –hp– Model 8614B Signal Source, as demodulated by negative polarity crystal detector, shows fast pulse capabilities. Sweep speed: 0.1 μsec/cm; vertical sensitivity: 5 mv/cm; RF frequency: 1350 Mc.*

ACKNOWLEDGMENT

The design group for the new signal sources included Alan L. Seely and Raymond H. Spoelman, and William W. Nelson made valuable contributions to the mechanical design. Industrial design was by Thomas C. Lauhon.

—Douglas A. Gray

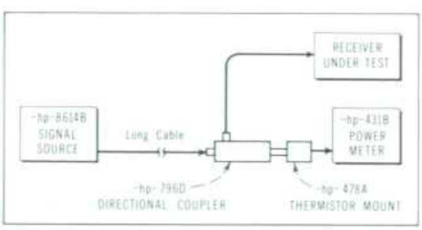

Fig. 4. *Instrument set-up for sensitivity measurements uses –hp– Model 431B Power Meter to calibrate signal source attenuator. Measured power level in dbm, modified −20 db because of coupler, is dialed into attenuator readout with thumbwheel on front panel. Attenuator may now be readjusted and dial will continue to indicate power level at coupler auxiliary arm.*

SPECIFICATIONS
–hp–
MODELS 8614B AND 8616B SIGNAL SOURCES

OUTPUT

FREQUENCY RANGE:
8614B: 800 to 2400 Mc
8616B: 1800 to 4500 Mc
Single, linearly calibrated control, direct reading within 2 Mc.

VERNIER:
ΔF control has 1.5 Mc range for fine tuning.

FREQUENCY CALIBRATION ACCURACY:
8614B: ±5 Mc or ±0.5%, whichever is greater.
8616B: ±10 Mc

FREQUENCY STABILITY:
Approximately 0.005%/°C change in ambient temperature; less than 0.003% change for line voltage variations of ±10%.
Residual FM: 8614B, less than 0.0003% peak; 8616B, less than 6 kc peak.

RF OUTPUT POWER:
8614B: At least 15 mw max controlled by attenuator.
8616B: At least 15 mw max, 1800 to 3000 Mc, and at least 3 mw max, 3000 to 4500 Mc, controlled by attenuator.
A second, fixed RF output (½ mw minimum) also is provided.

ATTENUATOR RANGE: At least 130 db.

ATTENUATOR ACCURACY:
±0.06 db/10 db from −10 dbm to −127 dbm; direct reading linear dial, 0.2 db increments. Backlash is less than 0.2 db.

MODULATION: Internal 1 kc square wave, external pulse, external FM.

PRICE:
–hp– Model 8614B: $1450.00
–hp– Model 8616B: $1450.00

Prices f.o.b. factory.
Data subject to change without notice.

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