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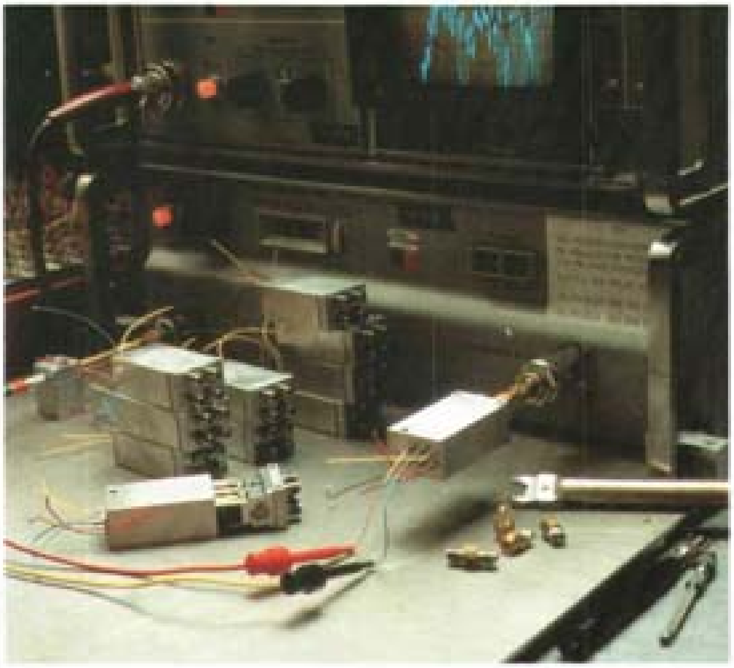

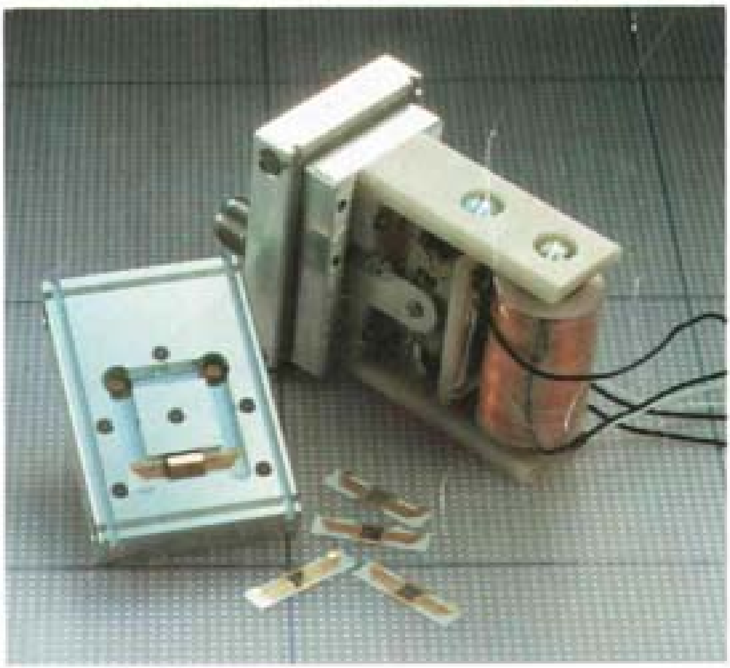

Microwave Products

SIVERSIMA

The Company SIVERS IMA

In January 1984 the two microwave companies Sivers Lab (est. 1951) and I.M.A. (est. 1975) were merged into one of the leading European supplier of microwave products: SIVERS IMA AB.

The main product lines are Switches, Rotary Joints, YIG's, VCO's and CSO's, all designed for radar, EW and instrumentation applications. Also included in the product range are microwaves kits, specially designed for Educational purpose.

SIVERS IMA, with a staff of over 150 employees, is an independent group in the Philips S& I division for professional equipment, with Development, Production and Marketing.

The world, and the future, is our territory

As a result of the highly specialized and concentrated product range, SIVERS IMA is by now a leading supplier to all systems houses in Western Europe. The worldwide network of Philips offices, and in some markets specialized agents, does not restrict us to just Europe but gives us the key to the whole world.

85% of our microwave equipment is sold to customers outside Sweden. In both cases there is a very close technical liaision between the customer and the technical staff in Stockholm, which ensures the customer the very best service.

SIVERS IMA is constantly maintaining the competiveness of the product range by an evolutionary process of employing latest techniques and processes. For the microwave products of tomorrow, SIVERS IMA has the availability to the inexhaustible source of knowledge and information of over 1,000 scientists in the Philips Research Establishments in Europe.

Modern machinery for a modern industry

The factory is well equipped with all types of modern machines. e.g. multifunction computer controlled lathes and milling machines, necessary to reach the higher standards of precision.

These production facilities enable us to produce parts ranging in size from fractions of millimetres up to metres with a precision of down to one thousand of a millimetre.

The excellency of the mechanical workshop was, and still is, one of the secrets behind the continued success of SIVERS IMA.

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* Specification for this product you will find in the brochure "Education in applied microwaves".

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Warranty

SIVERS IMA warrants each of its products to be free from defects in materials and workmanship. The limit of liability under this warranty is to repair or replace any product or part there of which shall, within one year after delivery to the original purchaser, be returned by the original purchaser to SIVERS IMA and prove to have been defective under proper use as determined by its examination.

General

YIG devices make use of the RF interaction between magnetically saturated **Y**ttrium-**I**ron-**G**arnet spheres and an optimized coupling structure. The interaction, which is a high Q resonance in the uniform precession mode of the ferrimagnetic resonance occurs at a centre frequency proportional to the magnitude of an applied DC-magnetic field and is independent of the mechanical dimensions. At the corresponding microwave frequency energy is coupled through the YIG-sphere, but rejected at other frequencies. By changing the coil current in the magnet, the field and thus the YIG resonance frequency is changed.

Advantages

- linear electronic tuning
- broadband tuning range
- high Q-value
- small dimensions

This catalog describes the current range of YIG-devices available. It includes bandpass and band reject filters, transistor oscillators, FET oscillators and tuning heads.

SIVERS IMA's solid microwave experience, in combination with an excellent technical staff and extensive in-house production facilities, gives a capability to meet requirements from most applications.

Definitions

Passband insertion loss

This is the minimum value of the attenuation within the passband.

Passband spurious and ripple

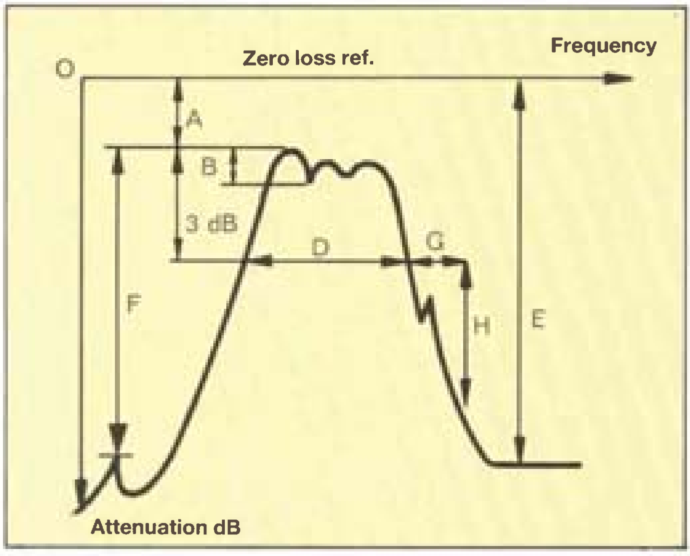
A passband spurious is an unwanted resonance in the YIG-sphere that tunes with a different rate to the main resonance and interferes with the passband at certain frequencies (cross-over). It appears as a notch in the passband. The degree of interstage coupling in the YIG-filter leads to passband ripple which varies across the tuning range. This effect could be difficult to discern from passband spurious, thus these two characteristics are specified together.

Bandwidth

The 3 dB bandwidth is the frequency band between the points where the attenuation has increased 3 dB from insertion loss.

Off resonance isolation

The ultimate attenuation far outside the passband of the filter. (See fig). It increases with the number of stages, typical values are 50 dB for 2-stage filters and 70 dB for 3-stage filters.



A = insertion loss
B = passband ripple and spurious
D = bandwidth
E = off-resonance isolation
F = off-resonance spurious
H/G = selectivity

Off resonance spurious

This is an unwanted resonance creating a passband with high attenuation at constant distance from the main resonance, and it tunes with the same rate.

The most important ones are the 210-mode and 540-mode spurious situated at lower and higher frequency, respectively, than the main resonance.

The spurious decreases the isolation value around its resonance frequency and its amplitude is specified to be the attenuation relative the insertion loss.

Tuning linearity

Tuning linearity is the maximum deviation of centre frequency from the best fit frequency-current line.

Frequency drift

This is the change in centre frequency associated with the change in base-plate operating temperature.

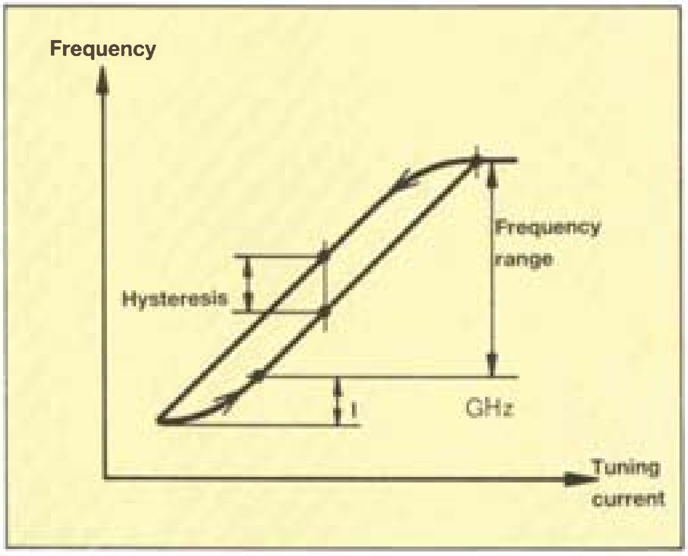
By careful orientation of the spheres this is minimized. Additionally, the YIG-spheres are kept at a constant temperature to prevent problems as temperature variations of the 3 dB bandwidth and the insertion loss.

The temperature stabilization is achieved by the use of heating elements applied to the spheres' carrying rods.

Hysteresis

The electromagnet is designed to provide low hysteresis. This is defined to be the maximum frequency difference obtained with any specific current, after the device has been tuned from the lowest or from the highest frequency of operation.

Hysteresis errors can be eliminated by starting the tuning cycle 1 GHz below the frequency range (item I in figure).



Passband VSWR

This parameter is related to 50 ohms impedance. The VSWR is measured at the best point in the passband. All YIG-filters have a passband VSWR less than 2:1. At frequencies on the skirt of the filter curve the VSWR increases and approaches total reflection value far from the passband.

Tuning sensitivity

This is the frequency change per mA tuning current. For SIVERS IMA YIG-filters the tuning sensitivity is 17.5 ±1.5 MHz/mA. The P-band filters have a tuning sensitivity of 15 ±1.5 MHz/mA.

Selectivity

A measure of the skirt slope of the filter as related to the 3 dB bandwidth. The filter can be characterized by a Chebyshev response. Critical coupling is assumed, which gives a skirt selectivity of 6 dB per bandwidth octave for each filter stage. (Item H divided by G, the latter expressed in octave bandwidth). Thus, if a two-stage filter has a 3 dB bandwidth of 30 MHz, theory predicts that the (12+3) dB bandwidth is 60 MHz and the (24+3) dB bandwidth is 120 MHz.

High and low-level limiting

The limiting power level is defined as the input power where the insertion loss has increased 1 dB.

Low-level limiting occurs at typically –25 dBm between the lowest useful frequency and twice that frequency.

High-level limiting occurs at power levels exceeding +10 dBm for frequencies above twice the lowest useful frequency.

Dual-channel filters

Two filters in the same magnet are especially useful for application where pre- and postselection is required around an RF-preamplifier.

The isolation between the channels is specified by the maximum permitted RF leakage from channel 1 input to channel 2 output with the remaining ports terminated.

Frequency tracking between the channels i.e. the difference between the centre frequencies is usually less than 10 MHz. Passband amplitude tracking is typically 1 dB and phase tracking within 30 deg.

Broadband filters

Filters with ultra broad 3 dB bandwidth can be supplied on special order.

Typical values

– L- and S-band	40– 80 MHz
– C-band	80–100 MHz
– X- and P-band	min 200 MHz

YIG-filters

YIG-tuned band reject filters

To protect sensitive receivers against the high level signals from near-by friendly sources YIG-tuned band reject filters present a practical solution. The band reject filter can be tuned over octave bands or more. As an alternative the design can be optimized for narrow tuning bands to stop some specific signals.

The tuning characteristics are basically the same as for the corresponding bandpass filters. Also the mechanical dimensions are identical. Band reject filters can be supplied with integrated driver circuits. Also in this case the data for tuning, power supply etc are identical with the corresponding bandpass filter/driver combinations.

TECHNICAL SPECIFICATIONS (−30°C to +70°C)

Model	Frequency range GHz	Rejection band 45 dB min MHz	3 dB band max MHz	Deviation from linear max MHz	Hysteresis max MHz	Outline
PM 7428L/00	1 – 2	10	200	± 3	3	A
PM 7428L/01	1.2– 1.45	6	50	± 1	2	A
PM 7428S/00	2 – 4	15	250	± 3	4	A
PM 7428S/01	2.7– 3.5	10	70	± 3	4	A
PM 7428C/00	4 – 8	15	250	± 5	8	A
PM 7428C/01	5.2– 5.9	20	150	± 3	4	A
PM 7428X/00	8 –12	20	250	± 5	8	B
PM 7428X/01	8.3–10.3	25	150	± 3	6	B
PM 7428P/00	12 –18	20	250	±10	12	B
PM 7428P/01	15.5–17.5	25	150	± 5	6	B
PM 7428XP/00	8 –18	6	200	±15	20	–

Insertion loss in the passband is typically better than 2 dB with a VSWR of less than 2:1. Off-resonance spurious are usually less than 5 dB.

Heater

All filters are provided with integrated heating elements for temperature stabilization.

Heater voltage: 20–30 V DC.

Heater current for temperature stabilization at lowest temperature:

two-stage filter	150 mA operating/300 mA surge
three-stage filter	250 mA operating/450 mA surge
four-stage filter	300 mA operating/600 mA surge
dual-stage filter	300 mA operating/600 mA surge

Environmental

All standard filters have a rugged mechanical design and will withstand severe shocks and vibrations.

Standard temperature range is 0–50°C but units with extended temperature interval and same data are available on request.

Temperature is refered to base plate.

YIG-tuned bandpass filters
Filter data

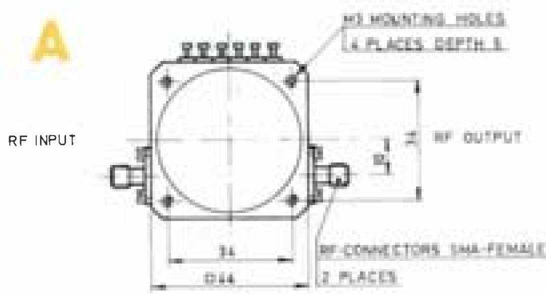
	Model	Frequency range GHz	Bandwidth 3 dB min MHz	Insertion loss max dB
Two-stage	SL 8010	0.5– 1	15	4[1]
	PM 7422L	1 – 2	20	3
	S	2 – 4	20	3
	C	4 – 8	25	3
	X	8 –12.4	25	3
	P	12 –18	25	3
Three-stage	PM 7423L	1 – 2	20	4
	S	2 – 4	20	4
	C	4 – 8	25	4
	X	8 –12.4	25	4
	P	12 –18	25	4
Four-stage	PM 7424L	1 – 2	20	5
	S	2 – 4	20	6
	C	4 – 8	25	5
	X	8 –12.4	25	5
	P	12 –18	25	5
Multioctave Two-stage	PM 7426	2.5–12.5	20	4[1]
	PM7427	2.5–18	20	5[1]
Three-stage	PM 7436/01	1 –18	15	8[1]

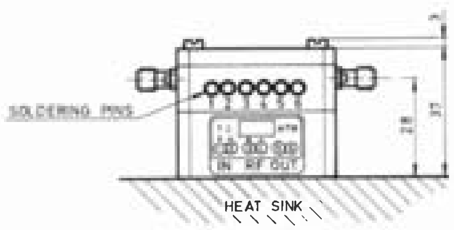
Dual-channel (isolation 40 dB between channels)

	Model	Frequency range GHz	Bandwidth 3 dB min MHz	Insertion loss max dB
Two-stage	PM 7421L	1 – 2	20	3
	S	2 – 4	20	3
	C	4 – 8	25	3
	X	8 –12.4	25	3
	P	12 –18	25	3

[1] Limiting level
SL 8010 –30dBm
PM 7426 –25 dBm (2.5–4 GHz)
PM 7427 –25 dBm (2.5–4 GHz)
PM 7436/01 –30dBm (1 –2 GHz)

A

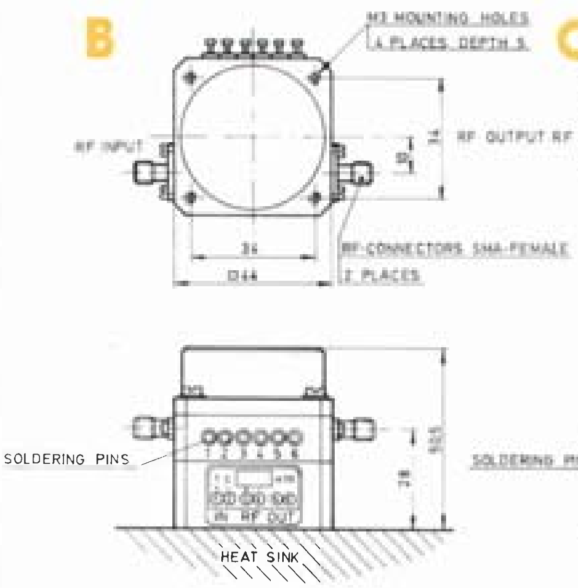




Tuning data

Off-resonance isolation min dB	Off-resonance spurious min dB	Combined passband spurious and ripple max dB	Tuning linearity max MHz	Frequency drift 0–50°C max MHz	Frequency tracking MHz	Selectivity dB/octave nominal	Hysteresis max MHz	Tuning coil resistance ohms	Tuning coil inductance mH	Outline
40	25	2	± 2	5	N/A	12	4	15	120	A
40	25	2	± 3	6	N/A	12	4	15	120	A
40	25	2	± 3	6	N/A	12	4	15	120	A
50	25	2	± 5	8	N/A	12	8	15	120	A
50	25	2	± 5	10	N/A	12	8	8	120	B
50	25	2	±10	15	N/A	12	12	8	120	B
60	40	2	± 3	6	N/A	18	4	15	120	A
60	40	2	± 3	6	N/A	18	4	15	120	A
70	40	2	± 5	8	N/A	18	8	15	120	A
70	40	2	± 5	10	N/A	18	8	8	120	B
70	40	3	±10	15	N/A	18	12	8	120	B
70	50	3	± 3	6	N/A	24	4	15	120	A
70	50	3	± 3	6	N/A	24	4	15	120	A
80	50	3	± 5	8	N/A	24	8	15	120	A
80	50	3	± 5	10	N/A	24	8	8	120	B
80	50	3	±10	15	N/A	24	12	8	120	B
50	25	2	±15	15	N/A	12	20	8	120	B
50	20	2	±20	15	N/A	12	20	8	120	B
70	30	3	±20	15	N/A	18	25	8	120	B
40	25	2	± 3	6	6	12	4	15	120	C
40	25	2	± 3	6	6	12	4	15	120	C
50	25	2	± 5	8	8	12	8	15	120	C
50	25	2	± 5	10	8	12	12	8	120	D
50	25	2	±10	15	10	12	12	8	120	D

B



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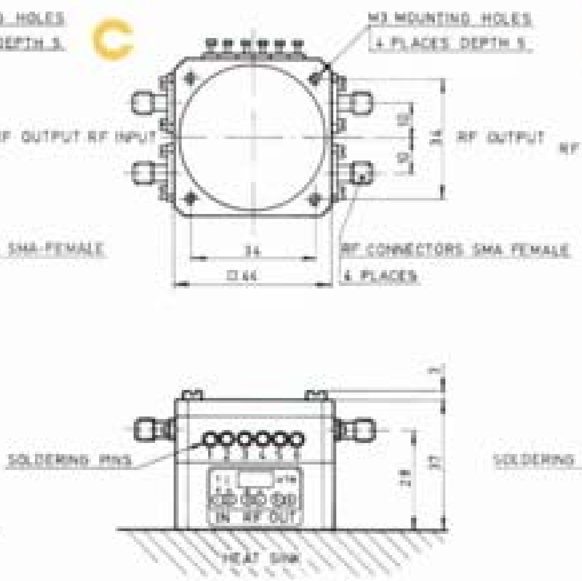

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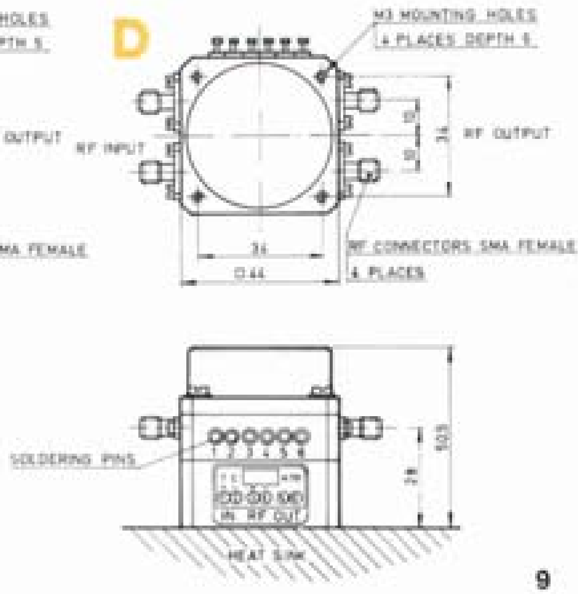


Integrated driver

Each filter as described earlier can be supplied as an integrated unit with a driver circuit for the tuning current.

General

The driver, basically a voltage-to-current converter, eliminates the complicated frequency alignment during installation. It also provides currents for the heating elements of the YIG resonators.

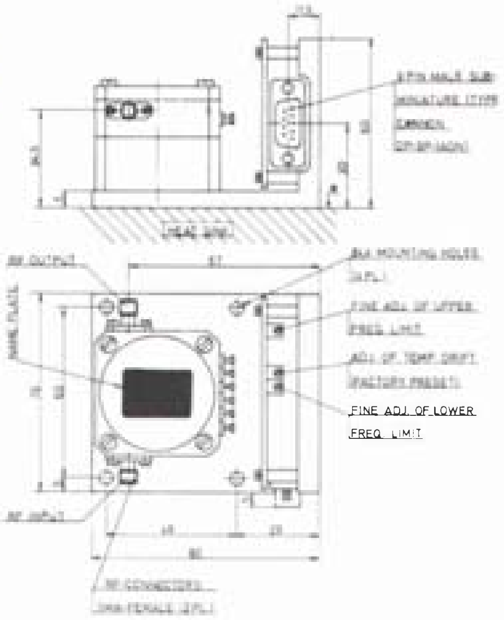
The YIG-device and the driver form a complete package, fully specified and ready-to-use after applying the command and power supply voltages.

The command voltage determines the operating frequency and by changing its value between 0–10 V, the device is tuned over the specified frequency range.

By mounting both YIG components and driver circuits in a common thermal mass, and by optimization of the tuning coil current, the filter driver package offers a number of advantages:

Improved stability
Improved linearity
Lower F.M. noise
No interface problems

E



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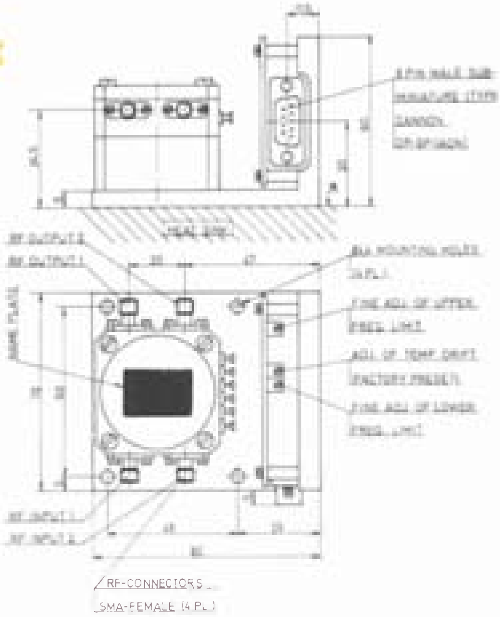

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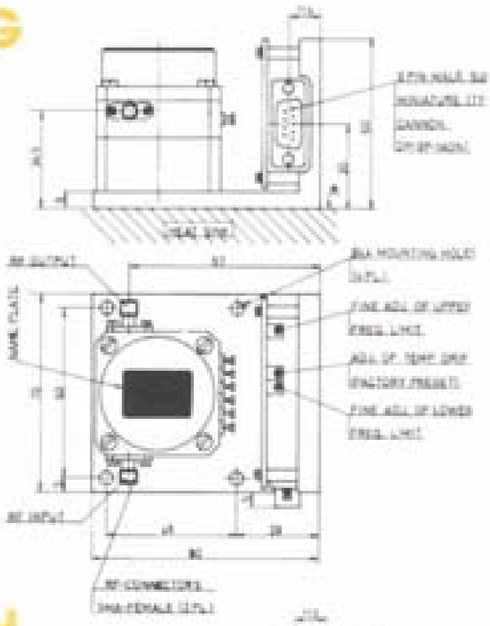

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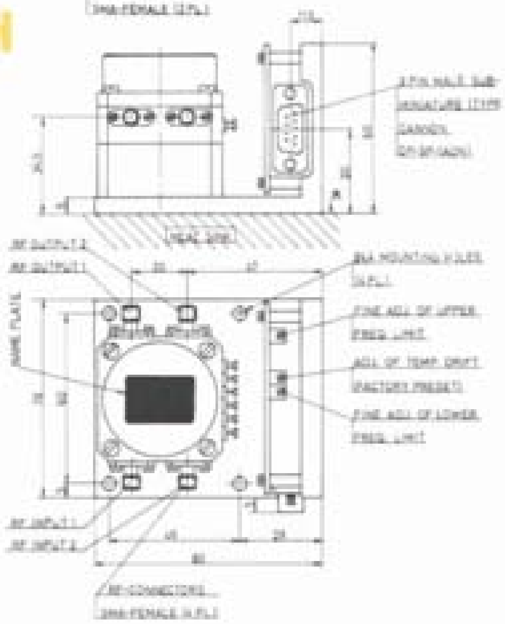


YIG-tuned filter/driver

Specifications 0–50°C

	Model Filter/drive	Model Filter	Frequency range GHz	Frequency accuracy MHz[1]	Tuning command sensitivity MHz/mV[2]	Tuning current[3] max mA	Weight g	Out-line
Bandpass								
Two-stage	**PM 7432L**	PM 7422L	1 – 2	±10	0.1	125	600	E
	S	S	2 – 4	±10	0.2	250	600	E
	C	C	4 – 8	±15	0.4	500	600	E
	X	X	8 –12.4	±20	0.44	775	750	G
	P	P	12 –18	±25	0.6	1300	750	G
Three-stage	**PM 7433L**	PM 7423L	1 – 2	±10	0.1	125	600	E
	S	S	2 – 4	±10	0.2	250	600	E
	C	C	4 – 8	±15	0.4	500	600	E
	X	X	8 –12.4	±20	0.44	775	750	G
	P	P	12 –18	±25	0.6	1300	750	G
Four-stage	**PM 7434L**	PM 7424L	1 – 2	±10	0.1	125	600	E
	S	S	2 – 4	±10	0.2	250	600	E
	C	C	4 – 8	±15	0.4	500	600	E
	X	X	8 –12.4	±20	0.44	775	750	G
	P	P	12 –18	±25	0.6	1300	750	G
Two-stage Dual channel	**PM 7431L**	PM 7421L	1 – 2	±10	0.1	125	600	F
	S	S	2 – 4	±10	0.2	250	600	F
	C	C	4 – 8	±15	0.4	500	600	F
	X	X	8 –12.4	±20	0.44	775	750	H
	P	P	12 –18	±25	0.6	1300	750	H
Bandstop								
Four-stage	**PM 7438L**	PM 7428L	1 – 2	±10	0.1	125	600	E
	S	S	2 – 4	±10	0.2	250	600	E
	C	C	4 – 8	±15	0.4	500	600	E
	X	X	8 –12.4	±20	0.44	775	750	G
	P	P	12 –18	±25	0.6	1300	750	G

Smaller size filters, drivers and digital tuning are available. Contact factory for further information.

The tuning command and the supply voltage are connected to a standard 9-pin connector (plug Cannon DE-9-P 1AON).

For supply current use following formulas:

Operational: n · 50 mA + 50 mA, where n is the number of stages (for temperatures below 0°C, use n · 75 mA + 50 mA)

Surge: n · 150 mA + 50 mA

Supply voltages: +15 ±0.2 V DC and −15 ±0.2 V DC. These voltages supply the driver electronics.

1) Frequency accuracy–the maximum deviation from nominal straight line across specified frequency and temperature range. This value includes effects of nonlinearity and temperature drift, but excludes hysteresis.

2) Tuning command 0–10 V DC covers full frequency range.

3) Main tuning coil supply voltage – 15 V DC, this value can be increased to max –28 ± 0.2 V DC to improve tuning speed of the device.

YIG-Oscillators

YIG-tuned oscillators

A complete range of YIG-tuned oscillators covering 1 to 18 GHz is available. Below 8 GHz uncapsulated bipolar transistors are used as active element and for higher frequencies, up to 18 GHz, GaAs FET's are used. As tuning resonator a YIG-sphere is used. The YIG-tuning gives excellent linearity and the high Q-value results in low noise and good frequency stability.

All oscillators have integral buffer amplifiers to achieve high flat output power and low pulling. For phase locking or modulation applications, a FM coil is standard in the oscillator.

The circuits are made in thin film hybrid technology with gold microstrip line on ceramic substrate.

The oscillators are housed in a cylindrical case serving as tuning magnet for the YIG-circuit as well as self shielding cover. The case is hermetically sealed and filled with an inert gas.

The combination of these technologies results in a microwave oscillator linearly tunable over octave and multioctave bands and able to withstand and operate under severe environmental conditions (wide temperature range, vibration, humidity etc).

Principle of operation

The YIG resonator serves as a tunable reactive element in the YIG-tuned oscillator. It is ideal for this purpose because of the great tunable range and high Q-value. The YIG-resonance determines the oscillation frequency, which is directly proportional to the applied magnetic field, as in YIG-filters. Hence, hysteresis, tuning speed and delay, tuning sensitivity and frequency drift appear similar to YIG-filters and are determined by the magnetic circuit.

Main types

The YIG-tuned oscillators are available in two basic types:

1. Bipolar transistor oscillators with low DC power consumption and covering 1–8 GHz.
2. FET-transistor oscillators for the range 8–18 GHz.

Power output

The output power from the oscillator as measured into a 50 ohm load.

The output power variation is measured over the frequency range. Variations due to changes in base plate temperature are also included.

Tuning linearity

Defined as the maximum frequency deviation from the best fit frequency – current line at 25°C.

The YIG-tuned oscillators exhibit the same excellent linearity as the filters. The effects from the variable reactance of the active element, either transistor or diode, is carefully reduced in the oscillator design.

Tuning current

For estimation of tuning current, use the following formula:

$$\text{Tuning current} \simeq \frac{\text{Frequency in MHz}}{\text{Tuning sensitivity}} \text{mA.}$$

Tuning sensitivity

This is the frequency change per mA tuning current. For most SIVERS IMA YIG-oscillators the tuning current sensitivity is 17.5 to 20 MHz/mA.

FM-modulation

For fast narrow-range FM or phase-lock operation, all oscillators are provided with an integral FM-coil. The FM-coil 3 dB bandwidth is the modulation frequency at which the tuning sensitivity of the coil is reduced to 0.7 of its DC-value. At rates above the –3 dB frequency, the modulation coil behaves as a low-pass filter with a rolloff of 6 dB/octave. The coil resistance is 0.5 ohm and the inductance approx 1 μH.

For high-rate modulation, most oscillators can be provided (option) with a fast FM-coil, which enables modulation frequencies exceeding 3 MHz with an associated frequency deviation greater than ± 200 MHz

Standard FM-coil characteristics

Coil used in	Tuning current sensitivity kHz/mA	Frequency deviation max MHz	Modulation rate (–3 dB) min kHz	Tuning current max mA
PM 7020L	310	±100	100	400
PM 7025S	310	±100	400	400
PM 7027C	310	±100	400	400
PM 7027SC	310	±100	400	400
PM 7027X	450	±300	400	800
PM 7027P	450	±300	400	800
PM 7027XP	450	±300	400	800

Frequency pushing/pulling

Pushing is the frequency shift caused by change in oscillator supply voltage and is expressed in MHz/V. It is measured at a maximal voltage change of ±0.5 V.

Frequency pulling is the peak-to-peak frequency shift for all phases of a specified load VSWR of 1.5:1.

FM-noise

The FM-noise characteristics are mainly determined by noise contents in the coil current. If a low-noise current source is used, the YIG-tuned oscillators will have a typical FM-noice of 85–100 dBc (SSB, 10 kHz from carrier, 1 Hz bandwidth).

Post tuning drift

This effect is most noticeable on the oscillators at the higher frequency ranges (8–18 GHz). After tuning from one end to the other of the frequency range, the oscillator frequency continues to shift a few megahertz during a time of up to 30 minutes. This is caused by temperature gradients in the magnetic shell.

Environmental

All standard oscillators have a rugged mechanical design and will withstand severe shocks and vibration. Additionally, the case also serves a magnetic shield.

Standard temperature range is 0–50°C but units with extended temperature interval are available on request. Temperature is referred to base plate.

SIVERS IMA can offer special solutions for low noise performance in vibrational environments. Contact factory.

SIVERS IMA standard YIG-oscillator screening proceedure include:

Temperature cycling	6 cycles –50°–+100°C (total 24h).
Burn-in	48 hours at +85°C (RF active)
Hermeticity	Fine and gross leak (He max 2x10–7 atm cc/sec.)

Final electrical tests on computer-testsystem (including ATP)

Extended screening can be provided on request (in accordance with MIL STD 883, 202 and 810) 100 % or batch-sample including:

High temperature storage
Mechanical shock
Vibration
Extended temperature-cycling
Temperature shock
Extended burn-in
Electrical endurance

YIG-tuned oscillators

(Temperature range 0°–50°C, other temperature ranges available on request)

Model	Frequency range GHz	Power output 25°C mW	Power variation dB	Harmonics dBc	Non-harmonics dBc	Frequency drift 0–50°C MHz	Linearity 25°C MHz	Pushing (max 0.5 V) MHz/V	Pulling (VSWR 1.5:1) MHz	Hysteresis MHz	Tuning sensitivity MHz/mA	Tuning coil impedance Ω	Tuning coil impedance mH	Bias supply V	Bias supply mA	Outline	Weight g
PM 7020L	1– 2	30	4	–13	–50	10	± 3	1	1	3	17	20	100	+15 V/–5 V	±100	I	350
PM 7025S	2– 4	30	4	–16	–60	10	± 4	2	1.5	4	20	20	100			K	200
PM 7027C	4– 8	30	4	–12	–60	20	± 7	1	2	7	18	12	110	+15 V/–5 V	±150	M	350
PM 7027SC	2– 8	25	6	–10	–60	20	±10	1	2	10	18	12	110			M	350
PM 7027X	8–12.4	10	4	–20	–60	20	± 5	1	3	10	17	7	90	+15 V	100	O	500
PM 7027P	12–18	10	6	–15	–60	40	±15	1	1	12	17	7	90	+15 V	150	O	500
PM 7027XP	8–18	10	6	–12	–60	40	±20	1	1	14	17	7	90	+15 V	150	O	500

Heater supply: nominal voltage 20–30 V. Current: 40 mA (steady state) to 150 mA (surge).
Broader frequency range available on request.
Please contact factory.

YIG-tuned oscillators/drivers

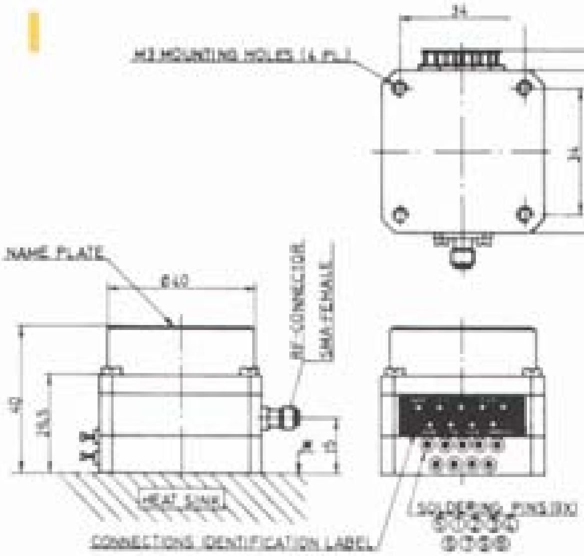
Model	Basic oscillator	Frequency range[1] GHz	Power output min at 25°C mW	Frequency accuracy MHz[2]	Supply voltage[3] and current surge value	Tuning coil current max mA	Weight g	Outline
PM 7030L	PM 7020L	1– 2	30	±10	+15 V/200 (250) mA	150	550	P
PM 7035S	PM 7025S	2– 4	30	±10	–15 V/200 (250) mA	250	400	U
PM 7037C	PM 7027C	4– 8	30	±15	+15 V/250 (350) mA –15 V/250 (350) mA	450	550	R
PM 7037SC	PM 7027SC	2– 8	25	±20	+15 V/250 (350) mA –15 V/250 (350) mA	450	550	R
PM 7037X	PM 7027X	8–12.4	10	±20	+15 V/200 (300) mA –15 V/100 (200) mA	750	700	T
PM 7037P	PM 7027P	12–18	10	±20	+15 V/250 (350) mA –15 V/100 (200) mA	1100	700	T
PM 7037XP	PM 7027XP	8–18	10	±40	+15 V/250 (350) mA –15 V/100 (200) mA	1100	700	T

1) Tuning command: 0–10 V for full frequency range.

2) Frequency accuracy–the maximum deviation from nominal frequency straight line across specified frequency and temperature range. This value includes effects of nonlineary and temperature drift, but excludes pulling, and hysteresis.

3) Supply voltages: + and –15 V (±0.2 V) DC. These voltages, supply the driver electronic circuits, the oscillator circuit, the heater for the YIG-sphere and the tuning coil current. The tuning coil is supplied from the –15 V only, but to increase the tuning speed a higher value (max –28 V) may be used. Add tuning coil current to the negative voltage current consumption.

I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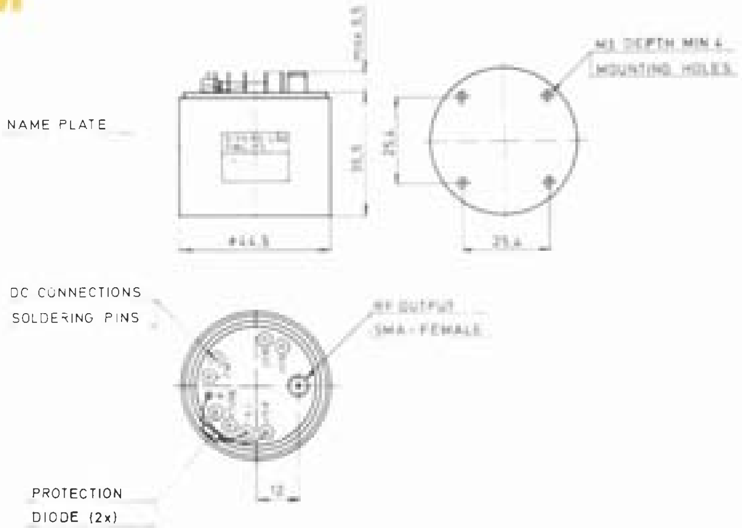
NAME PLATE
RF-CONNECTOR SMA-FEMALE
HEAT SINK
CONNECTIONS IDENTIFICATION LABEL
SOLDERING PINS (8X)

M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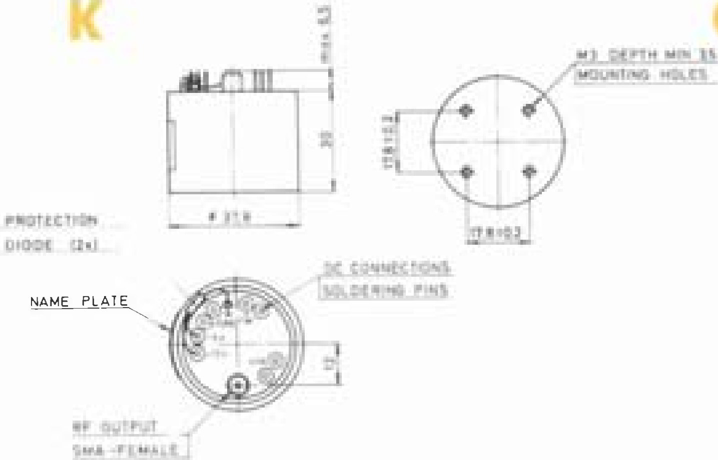
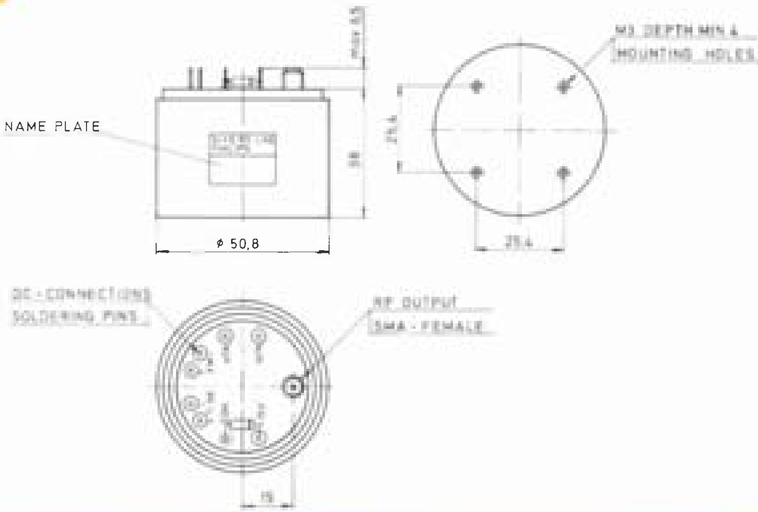
DC CONNECTIONS SOLDERING PINS
RF OUTPUT SMA-FEMALE
PROTECTION DIODE (2x)

K


M3 DEPTH MIN 3,5 MOUNTING HOLES
PROTECTION DIODE (2x)
NAME PLATE
DC CONNECTIONS SOLDERING PINS
RF OUTPUT SMA-FEMALE

O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M3 DEPTH MIN 4 MOUNTING HOLES
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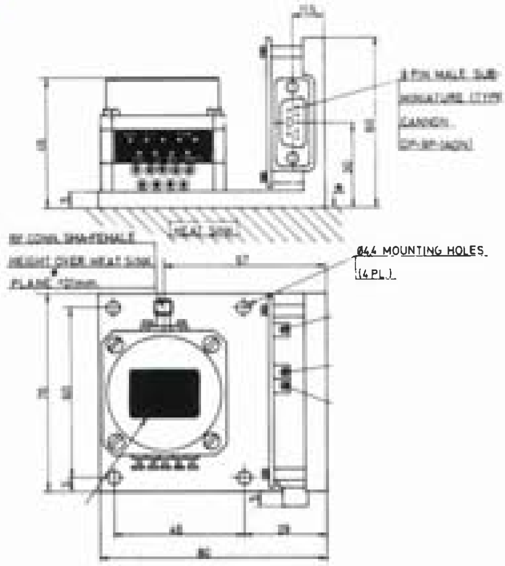
DC-CONNECTIONS SOLDERING PINS
RF OUTPUT SMA-FEMALE

YIG-Oscillators

P



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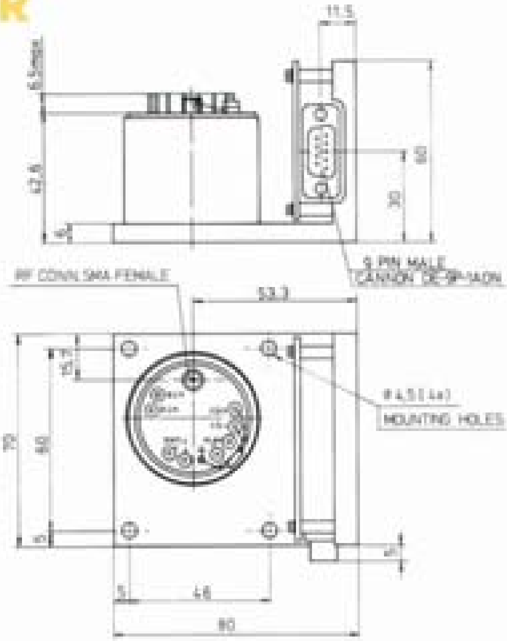

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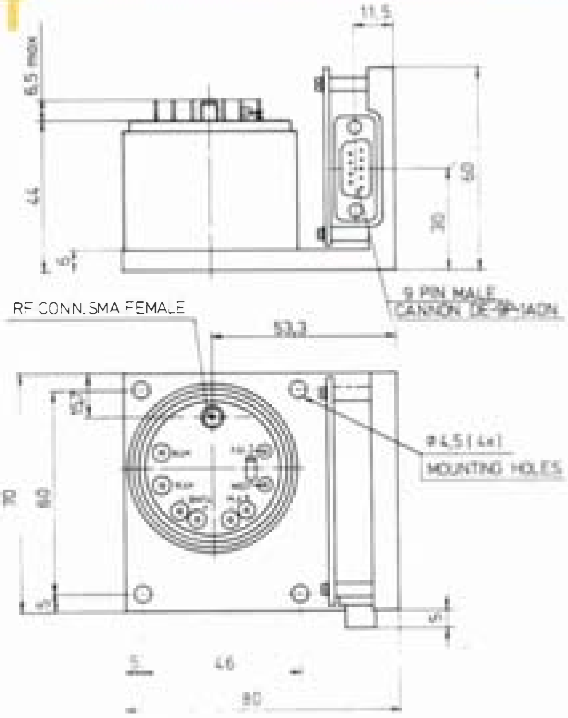

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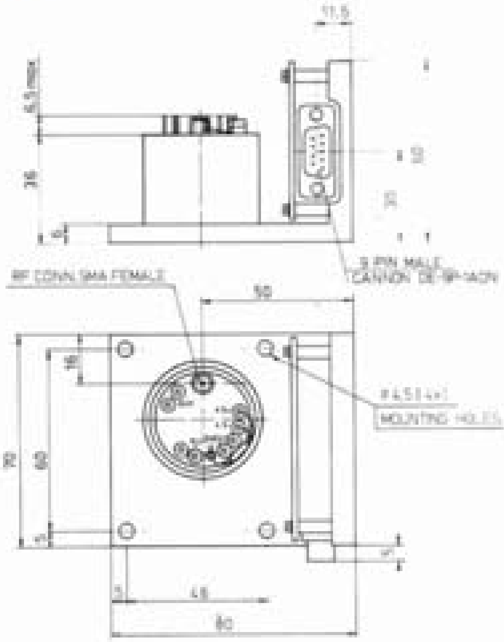
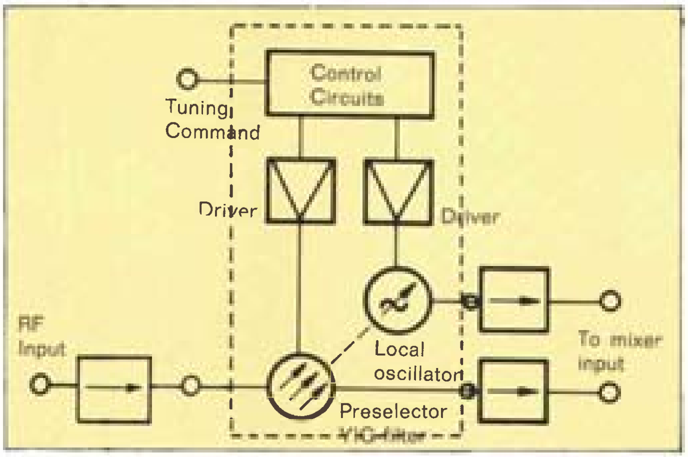


YIG-tuning heads

These all solid-state RF tuners cover octave bands. A basic outline of a "tuning head" is shown below.

The tuning head assembly consists of two fundamental components: a YIG preselecting filter and a tracking YIG-tuned local oscillator with a constant IF frequency off-set which is used in sweepable superheterodyne receivers and gives an outstanding spurious-free dynamic range. A single 0 to 10 volt analog tuning command will tune the assembly over the specified frequency range maintaining the oscillator/filter tracking.



Frequency accuracy

The frequency accuracy of the receiver is determined by total frequency deviation of the L.O. from the value corresponding to the input tuning voltage (worst case under all conditions including temperature).

A good temperature stability is obtained with a thermal continuity between a common baseplate and the RF-components/drivers.

Available IF frequencies

The IF frequency can be arbitrarily chosen, depending on system requirements. However, for the higher RF-frequency bands it is advantageous to use a high IF-frequency to simultaneously obtain a sufficient information bandwidth and a high spurious rejection. For X-band and P-band we recommend an IF of 160 MHz or higher.

Frequency tracking

The tracking requirements, determining the available (RF) information bandwidth and the noise figure are met by using compatible magnetic circuits together with electronic compensation in the current drivers.

An extensive burn-in prograam secure excellent stability over the tuning-head's entire service life.

Environmental

Standard temperature range is 0–50°C but units with extended temperature interval are available on request. Temperature is referred to base plate.

The SIVERS IMA YIG-devices can be guaranteed and qualified to rigorous MIL-specifications requirements. Selected units are qualified to MIL-E-5400 Class II and MIL-E-16400.

Typical values of tuning heads

	Preselector (four-stage)					Local oscillator					
Frequency range	Information[1] bandwidth	Insertion[2] loss max	Limiting level	IF frequency	Image[3] suppression	Output power	Power variation[5]	2nd harmonic	Non-harmonics	Accuracy[4] drift	Hysteresis
1 – 2 GHz	10 MHz	9 dB	+10 dBm	160 MHz	70 dB	30 mW	4 dB	–13 dBc	–50 dBc	± 6 MHz	4 MHz
2 – 4 GHz	10 MHz	9 dB	+10 dBm	160 MHz	70 dB	30 mW	4 dB	–16 dBc	–50 dBc	± 6 MHz	6 MHz
4 – 8 GHz	10 MHz	8 dB	+10 dBm	160 MHz	70 dB	30 mW	4 dB	–12 dBc	–50 dBc	±10 MHz	10 MHz
8 –12.4 GHz	10 MHz	8 dB	+10 dBm	160 MHz	70 dB	10 mW	6 dB	–20 dBc	–50 dBc	±15 MHz	14 MHz
12.4–18 GHz	10 MHz	8 dB	+10 dBm	160 MHz	70 dB	10 mW	6 dB	–15 dBc	–50 dBc	±20 MHz	25 MHz

Tuning voltage:	0–10 Volt
Min sweep time (across band):	20 msec
Flyback time:	5 msec
Sweep delay type:	150 μsec
Temp range:	0–50°C
Weight (approx):	2.5 kg (5 lb)

1) The bandwidth in which insertion loss and ripple and spurious spec are guaranteed. It is centered about the frequency given by the oscillator frequency plus/minus the IF frequency.

2) Worst point within the information bandwidth.

3) Insertion loss of the preselector at the L.O. frequency plus (or minus) the IF frequency.

4) Includes non-linearity and temp drift over a 0–50°C temp range. Does not included hysteresis.

5) Across frequency and temp ranges.

Voltage controlled oscillators
VCO

Very fast tuned wide band

The VCO's described below are standard designs, but they are usually not stock items. Our complete VCO program consist of several more, most of them customer specified, and we welcome your enquiries.

	PM 7611	PM 7612	PM 7614	
Electric tuning range[1]	6–7.25	6–7.25	12–14.5	GHz
Tuning linearity, BFSL incl temp	±30	±30	±60	MHz
Tuning sensitivity	130–170	125–250	250–500	MHz/V
Slew rate	1	15	30	GHz/μs
PTD, 200 ns to 1 ms**	2[2]	5	10	MHz
Modulation bw, 3 dB, 100 MHz	3	20	20	MHz
Pulling, VSWR 2:1 all phases	±1	±1	±2	MHz
Pushing	0.2	0.2	0.2	MHz/V
Residual FM	150	150	300	kHz
Power output	60	1[3]	1[3]	mW
Power output vs freq and temp	5	5	5	dB
Harmonics and subharmonics	–20	–20	–20	dBc
Spurious	–60	–60	–60	dBc
Supply voltage	±15	±15	±15	V
Supply current	250/250	250/250	250/250	mA
Tuning voltage	0 to +10	0 to –10	0 to –10	V
Tuning input impedance	>1	>0.400	>0.400	kΩ
Heater supply	28/3	28/4	28/4	V/A
Operating temperature	–25 to +71	–25 to +75	–25 to +75	°C
Warm up time	7	7	7	min

1) Other frequency ranges available on request.
2) 3 μs to 1 ms.
3) Higher output power optional.

Linearized Ultra Wide Band

The VCO's described below are standard designs, but they are usually not stock items. Our complete VCO program consist of several more, most of them customer specified, and we welcome your enquiries.

	PM 7600L/02	PM 7600S/02	PM 7600C/02	PM 7600X/00	PM 7600P/00	
Electric tuning range	1–2	2–4	4–8	8–12	12–18	GHz
Tuning linearity, BFSL incl temp	±30	±30	±40	±80	±120	MHz
Tuning sensitivity	60–140	150–250	300–500	300–550	400–800	MHz/V
Slew rate	1	2	4	4	6	GHz/μs
PTD, 10 μs to 1 s **	10	10	20	25	40	MHz
Modulation bw ±3 dB, 100 MHz	3	3	3	3	3	MHz
Pulling, VSWR 1.5:1 all phases	±1	±1	±1	±1	±1	MHz
Pushing	2	2	2	5	2	MHz/V
Residual FM	100	150	200	250	300	kHz
Power output	8–15	8–15	8–15	8–15	8–15	dBm
Power output vs freq and temp	5	4	4	5	6	dB
Harmonics and subharmonics	–15	–15	–15	–15	–15	dBc
Spurious	–60	–60	–60	–60	–60	dBc
Supply voltage	±20	±15	±15	±15	±15	V
Supply current	100/250	200/150	200/150	250/250	400/250	mA
Tuning voltage	0 to +10	0 to +10	0 to +10	0 to +10	0 to +10	V
Tuning input impedance	>1	>1	>1	>1	>1	kΩ
Heater supply	28/3	28/3	28/3	28/3	28/3	V/A
Operating temperature	0 to +60	0 to +60	0 to +60	0 to +60	0 to +60	°C
Warm up time	5	5	5	5	5	min

** Further data on PTD and settling time will be available on request.

Narrow band

The VCO's described below are standard designs, but they are usually not stock items. Our complete VCO program consist of several more, most of them customer specified, and we welcome your enquiries.

	PM 7622/01	PM7624	PM 7628/01	PM 7629	PM 7630	PM 7635/0X	
Electric tuning range	2.8–3.2	3.1–3.5	8.9–9.6	9–9.5	9.5–10.5	15.9–17.1	GHz
Tuning linearity, BFSL	±40	±2	±10	±10	±25	±25	MHz
Tuning sensitivity	10–40	40–50	80–90	20–40	100–200	125–175	MHz/V
Slew rate	5	0.1	1	10	–	0.5	GHz/μs
PTD, 40 μs to 1 ms * *	0.5	0.5	1	0.5	–	2	MHz
Modulation bw, ±3 dB, 100 MHz	10	3	1	3	–	3	MHz
Pulling, VSWR 1.5:1 all phases	±3	±0.5	±0.3	±5	±30	±1	MHz
Pushing	15	0.1	1	50	100	60	MHz/V
Residual FM	15	30	50	50	50	100	kHz
FM noise at 100 kHz	–95	–95	–85	–90	–90	–80	dBc/Hz
Power output	100	15–40	30–80	25–100	5–20	20	mW
Power output vs freq and temp	3	4	3	5	6	4	dB
Harmonics and subharmonics	–15	–15	–20	–20	–20	–20	dBc
Spurious	–60	–60	–60	–60	–60	–60	dBc
AM noise at 30 MHz	–95	–95	–95	–95	–95	–95	dBc/MHz
Supply voltage	–24	–24/+15	±15	–24	+12	–24/±15	V
Supply current	200	250/100	200/200	150	70	200/400/50	mA
Tuning voltage	0 to +30	0 to +10	0 to +10	±10	0 to –10	0 to + 10	V
Tuning input impedance	>1000	>4	>2	>1000	>10	>1	kΩ
Heater supply	–	28/3	28/3	–	–	–	V/A
Operating temperature	–25 to +75	–20 to +50	–40 +85	–40 to +85	–25 to +85	–25 to +70	°C
Warm up time	–	5	7	–	–		min

* * Further data on PTD and settling time will be available on request.

Voltage controlled oscillators VCO

Design considerations

SIVERS IMA voltage tuned transistor oscillators use advanced microstrip and MIC techniques to ensure high reliability in severe environments. The most important specification parameters can be listed in two groups as follows.

Primary Frequency
Band-width
Linearity
Tuning speed
Post tuning drift (PTD)
Power vs frequency

Secondary Noise
Spurious
Pulling
Pushing
Temperature sensitivity
Harmonics
DC supply
Frequency control (analog or digital)
Size and configuration
Environmental sensitivity

The first group of “primary” parameters concern those requirements which are highly important for system performance and also are critical in the design and choice of technology for the VCO. The “secondary” parameters are those which are either of less importance for system performance or which can easily be controlled in the design independent of choice of technology.

A number of different types of active devices and varactors may be used. The most important options are listed in fig 1 and some of their qualitative properties illustrated in fig 2.

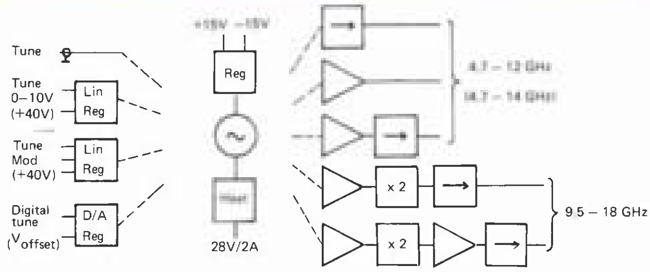
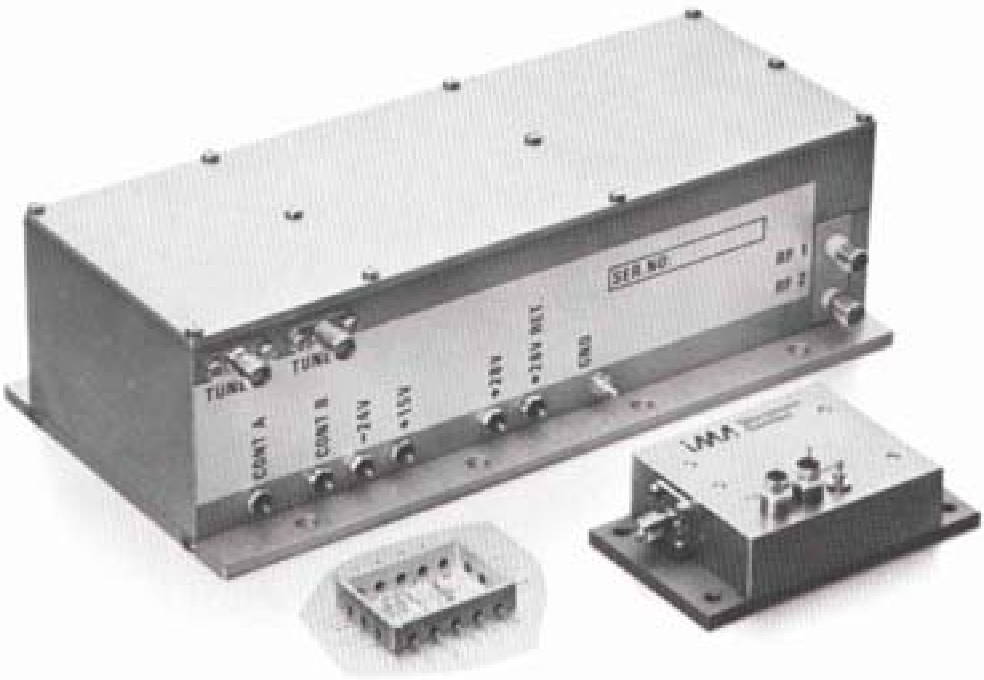


Fig 1

Type of Osc	Freq range	BW	PTD and settling	Harm/ Subharm
Bipolar Fundamental	→10 GHz	excellent	excellent	excellent
Bipolar Self Doubling	→14 GHz	excellent	excellent	poor
Gunn	6–18 GHz	poor	poor	excellent
FET	1–18 GHz	good	good	excellent

Fig 2



Fundamental frequency bipolar VCO's

In the lower part of the frequency range considered, the favoured oscillator type uses a fundamental frequency bipolar transistor. Two possible types of equivalent circuits are shown in fig 3 and 4.

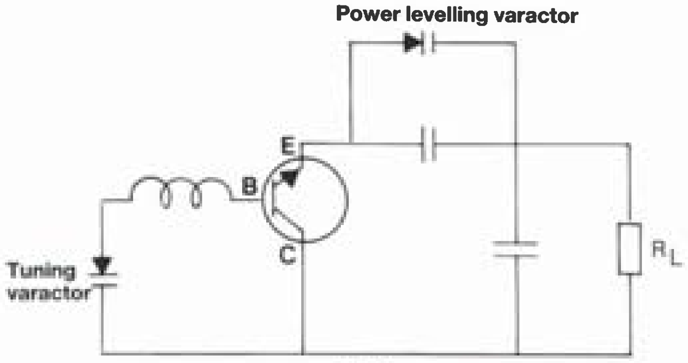


Fig 3

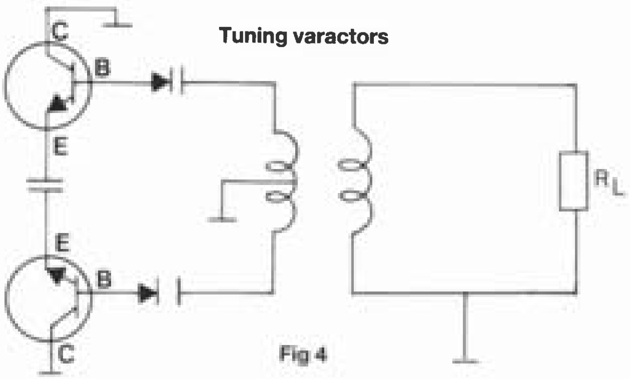


Fig 4

The circuit in fig 3 uses a simple common collector transistor with the tuning varactor included in the base-collector feedback loop. A second varactor may be included for power levelling in the load matching network.

The circuit in fig 4 uses two common collector bipolar transistors connected in a push-pull configuration. Two tuning varactors are connected as in the single transistor case. The push-pull oscillator offers higher power and also lower noise.

On the other hand the balun used as the output transformer is difficult to realize in microstrip technology, consequently the single transistor circuit is preferred by SIVERS IMA for fundamental frequency VCO's unless noise is critical. The tuning sensitivity curve typically achieved for such an oscillator is illustrated in fig 5.

In this case a silicon abrupt varactor is used. Changes in both tuning sensitivity and post tuning drift by other choice of varactors are discussed in the section on varactors below. Even without a post-amplifier the power variation over the tuning range is usually quite uniform.

The tuning sensitivity variation is about 10:1, which is typical for a silicon abrupt varactor in this type of circuit.

The maximum frequency for broad-band fundamental bipolar VCO's is about 10 GHz. Slew rate and tuning sensitivity is also discussed on page 22.

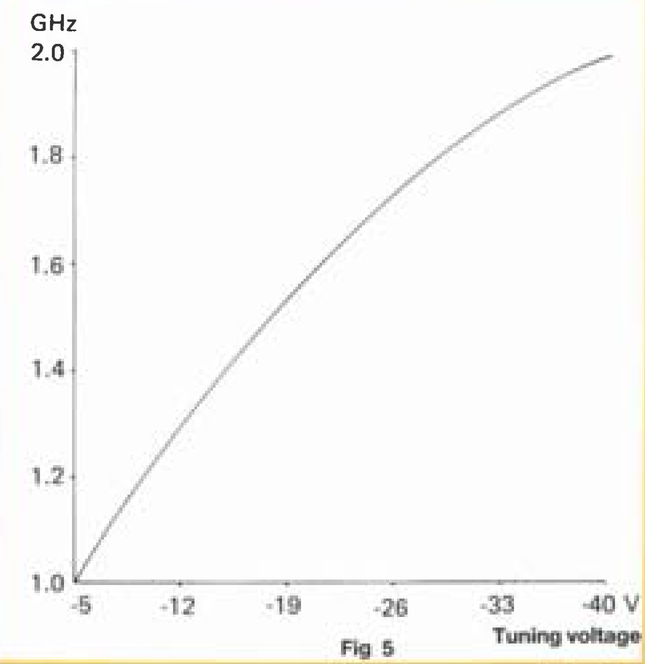


Fig 5

Self doubling bipolar VCO's

A simple modification of the equivalent circuit of fig 4 is shown in fig 6

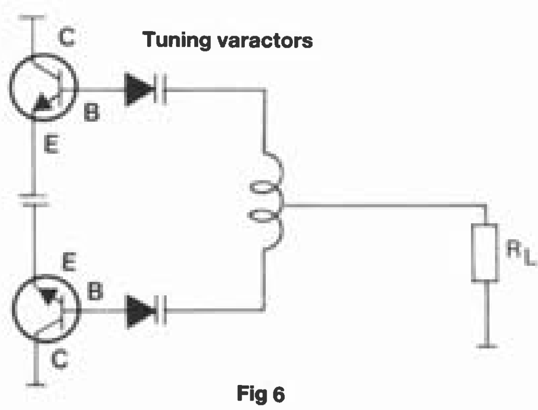


Fig 6

Voltage controlled oscillators VCO

With proper adjustment of the output network the fundamental frequency component may be depressed 20 dB below the second harmonic. Thus an oscillator putting out power at twice the oscillator frequency, i.e. a self doubling VCO, is obtained.
The performance of such a VCO is quite similar to a fundamental frequency VCO. In fig 7 a typcial tuning sensitivity variation of a self doubling VCO is illustrated.

Power variation across the band is somewhat higher but this can be levelled through the use of amplifiers as discussed below. Again the results refer to a silicon abrupt varactor. Other types are discussed below.

Self doubling VCO's easily cover frequency ranges up to well in excess of 14 Ghz. Higher bands can be covered using multipliers.

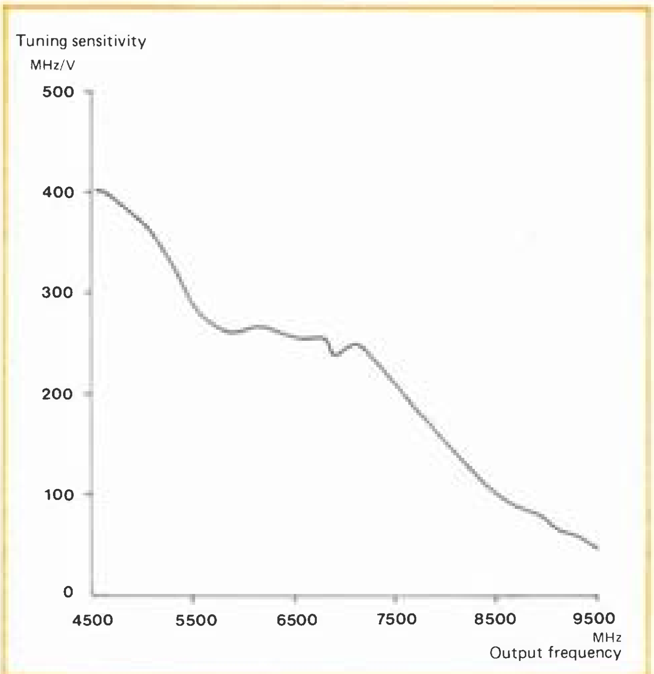


Fig 7

FET VCO's

Recent developments have made FET's available for oscillator applications. A suitable circuit for broadband VCO's is shown in fig 8.

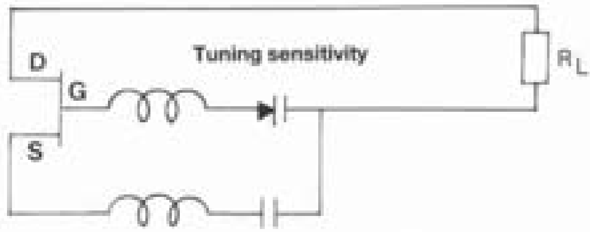


Fig 8

Although FET's show gain well into P-band the circuit of fig 8 will not operate satisfactorily up to 18 GHz because of the parasitic capacitance between source and drain caused by the usually large source bonding pad.

This large pad is provided on most FET's to reduce source inductance in amplifier applications. If FET's designed specifically for oscillator applications become available higher frequency operation will be possible. Some FET's may also work with reversed polarity between source and drain.

SIVERS IMA presently prefers self doubling bipolar VCO's, when necessary followed by external frequency multipliers, rather than FET VCO's because insert of the very low Q-value of broadband circuits associated with FET's. This low Q-value increases noise, pushing and pulling and in general degrades oscillator performance.

The bipolar transistor also shows up a much lower 1/f noise than FET's.

Varactors and their influence on tuning linearity and post tuning drift

The ideal varactor should have zero, i.e. very high Q-value, a capacitance variation giving a linear frequency – voltage relation and a capacitance which is an instantaneous function of applied voltage.

Needless to say real varactors have none of these properties. Silicon varactors have substantial losses. GaAs ones, in fact, come rather close to fulfilling the first requirement and their losses can usually be neglected in the frequency range considered.

An abruptly doped varactor in Si or GaAs gives much more rapid tuning at low voltages than at high. In limited voltage ranges hyper-abrupt varactors may come close to the ideal. Finally, surface charges due to immobile ions give a small but important capacitance contribution which changes with voltage and causes post tuning drift.

The time constant of this phenomenon ranges from microseconds to hours. Thermal effects may have similar consequences.

General selection rules are illustrated in fig 9.

	PTD and settling	Linearity	Q-value
Si abrupt	excellent	poor	good
GaAs abrupt	poor	poor	excellent
Si hyperabrupt	excellent	good	poor
GaAs hyperabrupt	poor	excellent	excellent

Fig 9

No device is ideal as a hyper-abrupt profile decreases Q and GaAs suffers from more problems due to surface charges with presently available technology.

The capacitance variation may be described by the expression:

$$C(V) = \frac{K}{\left(1 + \frac{V}{\phi}\right)^{\gamma}}$$

If no capacitances other than those of the varactor are included in the resonant circuit the frequency is given by:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Therefore a γ of 2 gives $f \sim 1 + \frac{V}{\phi}$ – i.e. linear tuning

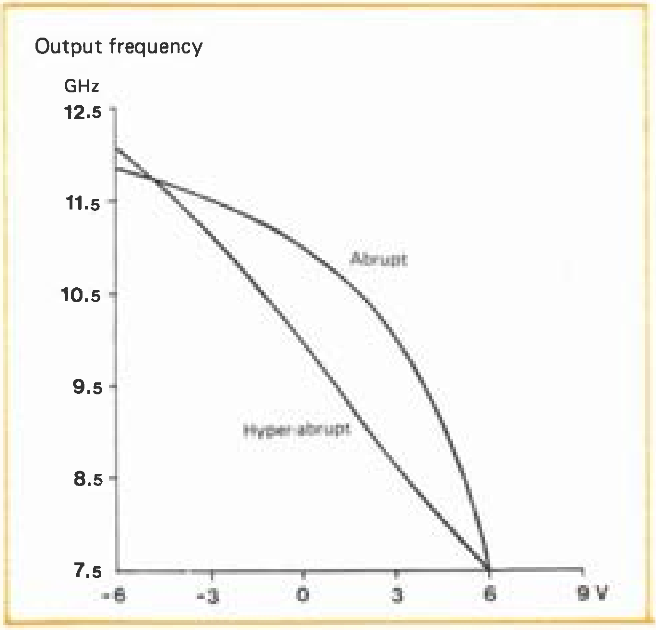


Fig 11

Fig 10 and 11 give a comparison of the nonlinearized tuning sensitivity curves with abrupt and hyper-abrupt varactors.

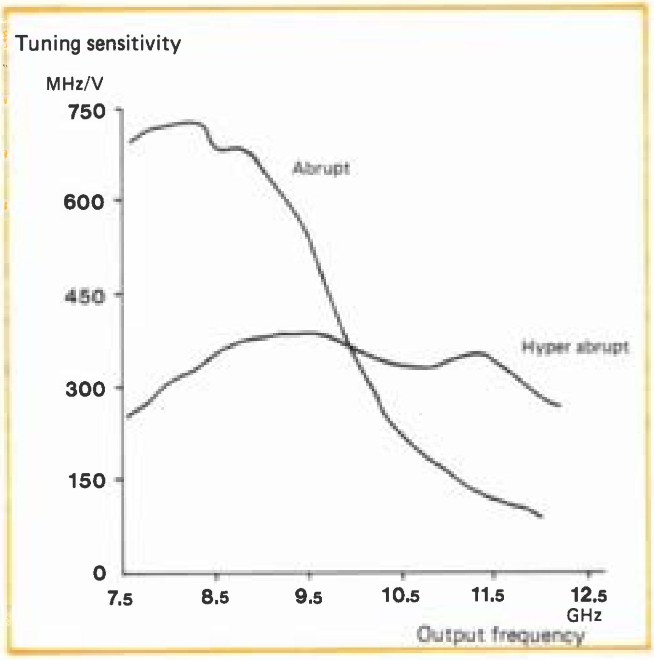


Fig 10

In fig 12 some actual results of measured post tuning drift are shown.

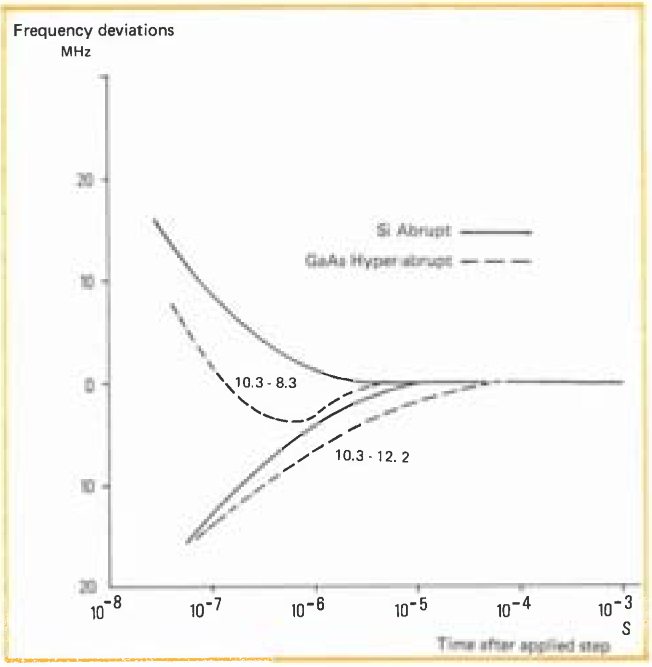


Fig 12

Voltage controlled oscillators VCO

Multipliers

As already mentioned above it is often advantageous to use multipliers in combination with lower frequency VCO's cover high frequency bands. Such multipliers are readily available. In fig 13 the measured output for a P-band source with a self doubling bipolar device in stage followed by a doubler is shown.

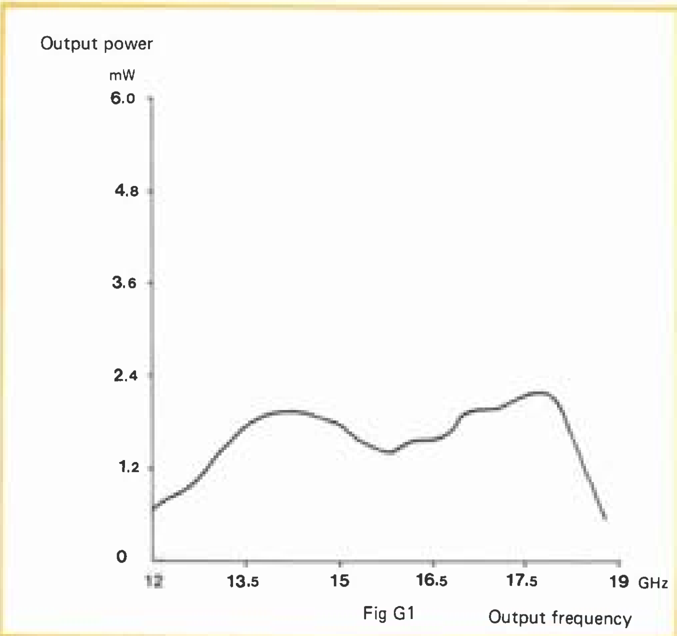


Fig 13

Linearizers

Often systems require a better tuning linearity than can be achieved even with a hyper-abrupt varactor or require linearity corresponding to what can be achieved with a hyper-abrupt varactor but with post tuning drift which can only be achieved with an abrupt silicon varactor. In such cases it is necessary to include a linearizer in the varactor bias circuit.

A practical circuit for such a linearizer is shown in fig 14. The price paid for including this linearizer is a decrease in slew rate and the introduction of noise on to the varactor bias line. With the actual circuit in fig 14 a typical slew rate of 20 V/μs is obtained.

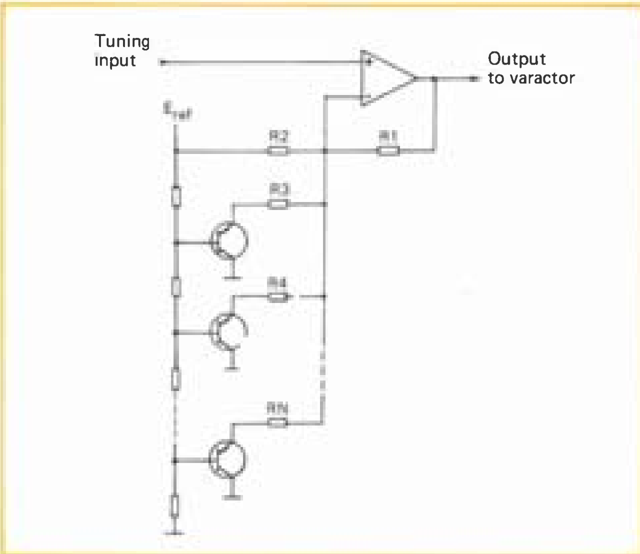


Fig 14

A typical result for a linearizer designed to give best fit to a straight line frequency vs voltage curve is shown in fig 15.

It should be noted that the use of a linearizer does not prevent direct access to the tuning varactor from beeing used for high rate modulation.

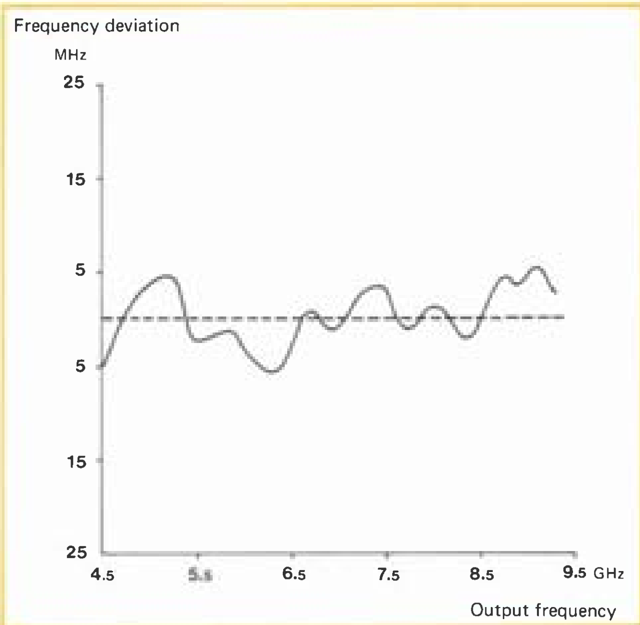


Fig 15

Al_2O_3 vs PTFE substrates

Two alternative technologies may be used for broadband VCO's. The simplest technology uses stripline in PTFE substrates and packaged semiconductors throughout. The alternative is to use microstrip on Al_2O_3 and unpackaged semiconductor chips in which case it is necessary to seal the entire unit hermetically.

The reason for removing the chip packages is to avoid parasitics. The capacitance of the ceramic in a transistor or diode package is often of the same magnitude as that of the chip itself and therefore it very severely limits the bandwidth. Packages also generally have more series inductance than a chip connected directly to a 50 ohm line.

At low frequencies, when larger capacitances are used, e.g. in varactors, the effect is less serious but nevertheless exists. It is therefore generally true that better performance can always be achieved with Al_2O_3 substrates. A practical example of tuning curve measured on two equivalent VCO's on PTFE and Al_2O_3 respectively is shown in fig 16.

Also, from a thermal point of view, Al_2O_3 may offer advantages. For instance, a series connected varactor on PTFE has very high thermal resistance and, although only little power is dissipated, the poor thermal path may influence post tuning drift.

Finally, the higher dielectric constant of Al_2O_3 results in smaller dimensions and less sensitivity to vibration and noise.

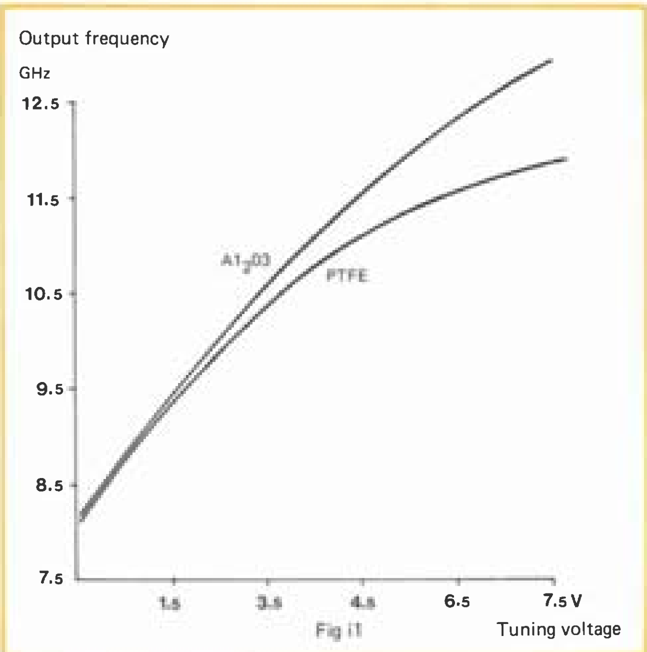


Fig 16

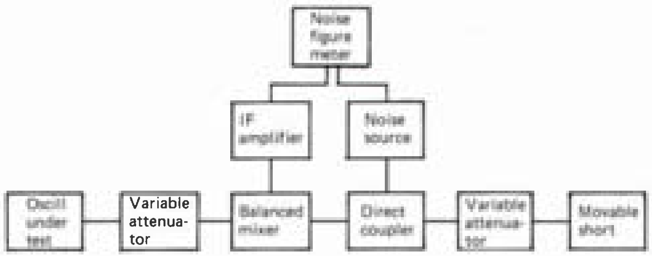


Fig 17. Test set-up for noise measurement

LO noise

The nominal noise of a Gunn or transistor oscillator 30 or 60 MHz away from the carrier is low enough so that it does not contribute to the noise figure of a good balanced mixer. However, practical experience has shown that certain caution must be exercised to avoid an extra contribution.

To explain this effect reference is made to fig 17. This figure shows a block diagram of the receiver with noise meter and with the antenna replaced by a variable attenuator and a movable short. Using this set-up the effect of an antenna mismatch combined with a long line effect can be evaluated. LO-power leaking through the mixer will be reflected by such a mismatch and the frequency dependence due to the long line effect will act as a discriminator and convert LO FM-noise into receiver noise.

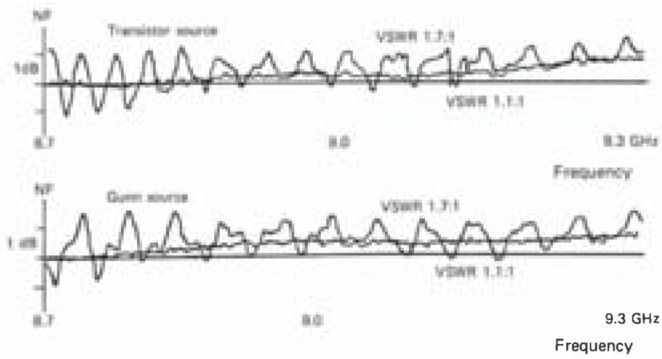


Fig 18. Noise figure for balanced mixer. VSWR on signal input port

The practical importance of this effect is shown in fig 18 which gives the measured effect on noise of an antenna mismatch. This effect is especially important in frequency agile systems as the wide band nature of the LO enhances FM-noise. An isolator close to the mixer in the antenna branch will eliminate the problem.

Voltage controlled oscillators VCO

Frequency agile local oscillators

Frequency agility offers many advantages with respect to detection probability in radar systems. In order to fully utilize these advantages it is necessary to ensure that the noise figure of the receiver remains undegraded in the frequency agile mode. Sometimes it is also required that the radar may be switched into an MTI mode.

The accutune magnetron is electrically tunable and may offer a tuning range of up to about 1 GHz. The spin tuned magnetron has a tuning range of about 0.5 GHz at X-band, but is not electrically tunable, i.e. it cannot be made to follow the frequency of a source with arbitrarily varying frequency. Nevertheless the spin tuned magnetron is of great interest because of its high tuning speed.

As an example the maximum frequency with which an accutune magnetron can sweep a 1 GHz band is about 20 Hz, i.e. df/dt~40 kHzμ/s, whereas the df/dt of a spin tuned magnetron is about 1 MHz/μs. If electric tuning of the magnetron is available it is possible to design systems where the magnetron follows the LO frequency. If a limited number of discrete frequencies are used, crystal controlled LO's can offer full MTI capability.

Cavity/Gunn oscillators CSO

The Gunn CSO's described below are standard designs, but they are usually not stock items. Our complete CSO program consist of several more, most of them customer specified, and we welcome your enquiries.

	PM 7642	PM 7644	
Centre frequency[1]	9.25	10.5	GHz
Mechanical tuning range[2]	±50	–	MHz
Frequency/temperature	75	80	kHz/°C
Pulling, VSWR 1.2:1 all phases	±1	±1	MHz
Pushing	5	0.5	MHz/V
FM noise at 10 kHz	–59	–59	dBc/kHz
Power output	150	100	mW
Power output vs freq and temp	3	3	dB
Supply voltage	10.5	15	V
Supply current	1	1.2	mA
Operating temperature	–25 to +55	–40 to +60	°C

[1] Other centre frequencies available on request.

[2] Electrical tuning 6 MHz.

Design considerations

High stability fixed frequency oscillators

Fixed frequency microwave oscillators are realized by combining an active semiconductor device with a frequency stabilizing resonant circuit. The active device may be a bipolar transistor, FET or an active diode such as an impatt, Gunn or baritt. In practice impatts and baritts offer few advantages and are rarely used in modern circuits. When frequency stability is important it is necessary to store a large amount of reactive energy in the resonant circuit and distributed resonators such as TM or TE cavities or dielectric resonators are the preferred choices.

Frequency stability may be of importance over very long periods of time such as years but also for very short periods like microseconds.

In the latter case it is customary to speak of FM-noise rather than frequency stability. The rms frequency deviation Δf rms is related to device and circuit parameters through the relation ship.

$$\Delta f_{rms} = \frac{f}{Q_{ext}} \sqrt{\frac{MkTB}{P}}$$

Thus low Δf rms calls for a high Qext, a low device noise measure M, a high microwave power P and a narrow bandwidth B.

Resonator properties at 9 GHz (fig 1)

Resonator	Q unloaded	Temp coeff	Size	Vibration sensitivity	Mech tuning	Moisture sensitivity
TM_{010} cavity	10 000	15 ppm/K copper 1.5 ppm/K invar	–	+	+	– + (hermetic)
TE_{011} cavity	20 000	15 ppm/K copper 1.5 ppm/K invar	–	–	++	+ (hermetic)
Dielectric	5 000	1.5 ppm/K	+	++	–	+

Active device properties (fig 2)

	f max GHz	Noise measure dB	Power efficiency %
Bipolar	6	15	10–20
FET	18	30	10–30
Gunn	50	15	1– 5

Gunn diode, TM_{010} cavity

The long term stability is influenced by

- drift in semiconductor device reactance
- drift in resonant frequency of cavity or dielectric resonator
- variation in humidity
- variation in ambient temperature
- RF load variation (pulling)
- bias voltage variation (pushing)

The last two of the above factors may be controlled through the use of external isolators and regulators but the remaining ones are determined by the technology of the oscillator itself. An overview of the properties of the most commonly occuring resonators and semiconductor devices are given in fig 1 and 2. It should be noted that the output power of the oscillator may be boosted through the use of external amplifiers. The power P occuring in the expression for Δf rms above is the output power of the oscilator itself. Amplification will increase power and the noise MkTB in the same ratio and thus leave Δf rms unaffected.

In order to have as high a Qext as possible it is desirable to couple the load to the resonator very lightly so as to obtain unloaded Qext. In doing so, however, P is decreased and therefore an optimum load coupling usually exists.

Specifications of a high preformance CSO (fig 3)

Frequency range	9100–9200	MHz
Output power	150	mW min
RMS frequency deviation		
f_m = 500 Hz	0.15	Hz/Hz max
f_m = 1000 Hz	0.13	Hz/Hz max
f_m = 10 kHz	0.07	Hz/Hz max
f_m = 100 kHz	0.04	Hz/Hz max
Output power variation with temperature (–10 to +65°C)	+/–0.5	dB max
Pulling, VSWR 1.15, all phases	+/–50	kHz max
Pushing	100	kHz/V max
Temperature range	–10 to +65	°C

Oscillator design

A high preformance specification is given in fig 3. On their own the most difficult requirements to satisfy are those of FM-noise and long term stability. Both these requirements call for a very high external Q-value of the oscillator cavity. In order not to dissipate too much of the available power in the cavity it is necessary to use a cavity with a high unloaded Q-value. The choice of cavity is further dictated by the requirement of wide operating temperature range. This excludes very high-order cavity modes. Using such high-order modes it would be impossible to suppress unwanted modes under all operating conditions. Thus it seems natural to use either a TM_{010} or a TE_{011} cavity. In the present case is chosen TM_{010} because it is simpler to couple the diode to this cavity and because the thermal compensation (which will be discussed below) is simpler with this choice. The cavity is constructed in silver plated invar except for the wall in which the diode is mounted and because the expansion of a single cavity wall does not effect the frequency or indeed any dimension of the cavity. Using this design it is possible to realize an unloaded Q of about 7000.

The diode is mounted near the centre of one of the end walls and coupled electrically into the cavity. The load is coupled to the cavity using an electric probe in the end wall.

In order to compensate for the thermal expansion of the cavity and the frequency shift caused by the thermal variation of the diode a small piece of compensating dielectric is mounted opposite the diode.

The measured FM-noise of an oscillator, meeting the specification in fig 3, is shown in fig 4.

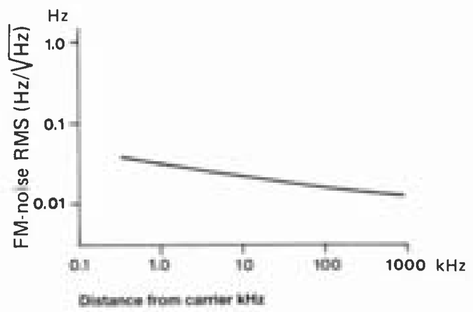


Fig 4

Long term frequency stability

There are three major contributions to the long term frequency drift of an oscillator of the type considered here. Thermal expansion of the cavity and thermal variation of the diode reactance are most often considered.

With the very high degree of stability achieved here it also becomes very important, however, to consider the contribution from the variation of the moisture content of the gas filling the cavity.

Firstly consider the case of a hermetically sealed oscillator and refer to figure 5. The motive for choosing invar as the base material for the cavity is obvious when considering curve D referring to measurements on an oscillator with a copper cavity. In this case the temperature coefficient is about 15 ppm/°C.

Proceeding to curve B it is seen that the empty invar cavity has a measured temperature coefficient of somewhat more than 1 ppm/°C which is of the same order of magnitude as the coefficient of the thermal expansion of invar itself. Curve C shows that in an actual oscillator the device itself including its package makes a large contribution to the frequency drift. In order to compensate for the sum of the contributions from the invar and from the diode a compensating dielectric is introduced resulting in curve A with a temperature coefficient of about 0.5 ppm/°C. For an individual oscillator even this value can be improved. To complete the picture the power stability is illustrated in figure 6 for a particular case of an partially compensated oscillator.

If the oscillator is not hermetically sealed or has its moisture content controlled in some other manner the stability degrades considerably. Figure 7 gives the result for various relative humidities. It is seen that particularly at high temperatures a frequency drift in excess of 10 ppm/°C may be obtained.

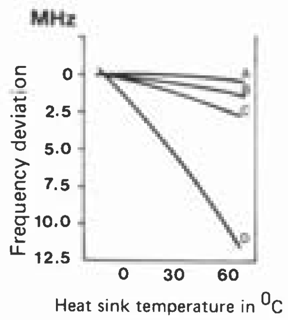


Fig 5

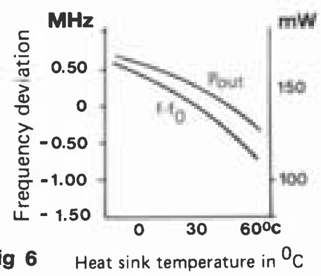


Fig 6

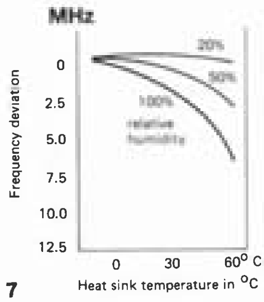


Fig 7

A: Oscillator with Invar cavity and dielectric compensation
B: Invar cavity
C: Oscillator with Invar cavity
D: Copper cavity

DRO

As noted in the introduction dielectric resonators often offer advantages in size, weight and insensitivity to humidity. This last point merits further explanation. Dielectric resonators have existed for many years with excellent Q-values and temperature coefficient but have suffered from a major drawback, because the dielectric materials have been hydroscopic and required hermetic sealing. This difficulty has now been overcome with new materials which are virtually non-hydroscopic and it is these materials which are used in the SIVERS IMA range of DRO's. No detectable long term frequency drift of drift due to water absorption has been observed in a number of oscillators which have been operated under adverse climatic conditions for extended periodes.

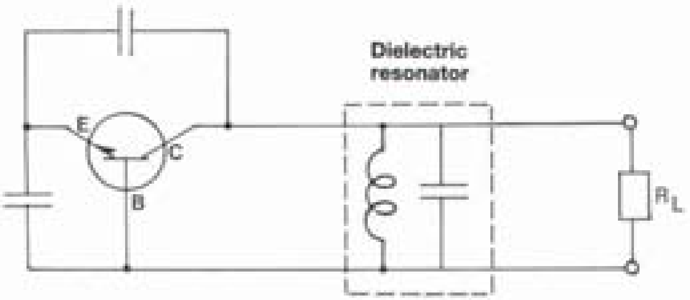


Fig 8.

Bipolar DRO's

At low frequencies the bipolar transistor is the preferred active device for DSO's. SIVERS IMA oscillators are built in stripline or microstrip technology and are usually based on the equivalent circuit of fig 8.

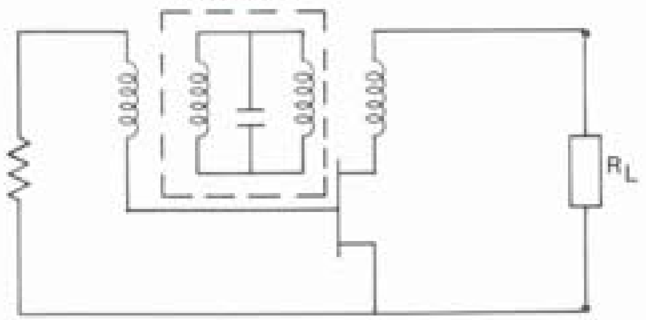


Fig 9

FET DSO's

At frequences above 8 GHz bipolar transistors can no longer be used but FET's offer an alternative. Their power efficiency is usually even better than that of bipolar transistors but the device noise measure is considerably higher at any given modulation frequency. Microstrip is again a useful technology and SIVERS IMA usually bases its oscillators on a resonant source drain feedback circuit as illustrated in fig 9.

The material composition can be chosen to give virtually zero temperature drift of the resonant frequency at a given temperature. However, it is usually better to select a temperature coefficient which will compensate the drift due to the active device resulting in a frequency stable oscillator. In practice, variation within production runs and over temperature leads to imperfect compensation. The final specified stability depends on a number of compromises and typical specifications are given on page 27. These specifications all refer to the oscillator itself. Amplifiers may be integrated to boost output power. It is also possible to obtain somewhat improved frequency stability at the expense of oscillator power by increasing the loaded Q-value.

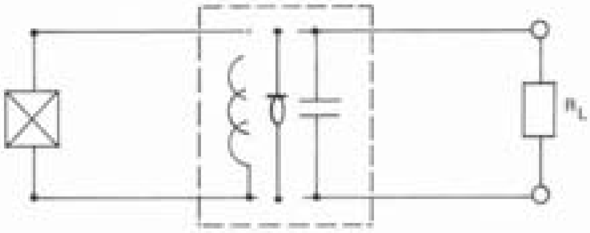


Fig 10

Gunn DSO's

Gunn diodes may replace FET's above 8 GHz and they are also useful at higher frequencies than 7.5. Their noise performance is comparable with that of the bipolar transistors. Oscillator technology is again or microstrip with a circuit similar to what is used with bipolar transistors as illustrated in fig 10.

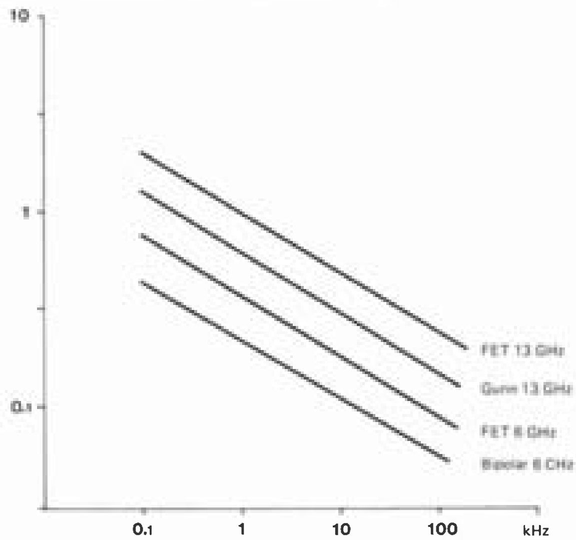


Fig 11

Noise

A comparison of measured noise performance of the oscillators where specifications were listed in on page 27 is given in fig 11.

Waveguide switches

General

This section describes all standard manual and automatic designs of waveguide switches at present. For particular applications special types of switches may be designed.

Electromechanical switches are widely used in microwave systems:

- in satellite communication for redundancy applications
- in radar for test purpose
- in test equipment to select various signal paths etc

Common for all mechanical switches is:

- high isolation
- low insertion loss
- high power capability
- long life

General description

All waveguide switches have a square stator with four ports. The rotor, which is fitted in the stator, has two or three channels. Electrical continuity between the rotor and the stator waveguide is achieved by means of quarter wave chokes. These chokes give extremely high isolation between the rotor waveguide channels and also ensure unchanged high electrical performance throughout the lifetime of the switch (no sliding contacts).

Accurate angular alignment between the rotor and the stator is for manual models achieved by a roller and indent construction. For automatic models the alignment is achieved by both electrical and mechanical means.

All models have a low VSWR and high power-handling capacity. They withstand the full power rating of the waveguide and can be pressurized up to 0.2 MPa (2 ATO) for higher power applications.

All switches have E-plane bends for small dimensions.

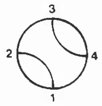
All switches are made of copper-free aluminium alloy. The rotor and stator are chromated. The cover on the automatic models is painted. All parts are made of corrision resistant material.

The flange connections are normally standard as plain flanges with threaded holes. On PM 7295–99 models the holes have steel helicoil inserts, other models on request. Special flange drillings can be made on request.

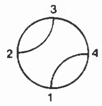
Configurations

All switches have a square stator with four ports. The rotor have two or three channels. The following configurations are available:

Four ports – two channels (transfer)

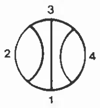


Position 1

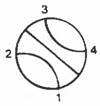


Position 2

Four ports – three channels

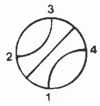


Position 1



Position 2

Position 3



Position 4

Actuators

Both manual and automatic switches are made. The automatic types can be fail-safe or latching. The **fail-safe** type always returns to the de-energized position when power is disconnected. In the energized position a small holding current is required. Once energized the **latching** type is stable in its position and no holding current is required.

In applications like safty-circuits, where in case of power supply failure it is required that the switch returns to its original position, a fail-safe type is the natural choise. In other applications it might be an advantage to have no holding current.

Auxilary contacts for position indication are built-in in most models. In some models these contacts also include circuits for transient suppression, which means an effective protection against harmful transients. Also built-in are reversed polarity protection circuits.

A positive damping device in the automatic types absorbs most of the kinetic energy, which means an almost completely bounce-free switching.

W/G switch PM 7286M without and with manual override

Waveguide switches

General data (applicable to all types)

Configuration: Transfer (two-channel) except PM 7305 which is three-channel

VSWR: For rectangular waveguide 1.05
(PM 7288 and PM 7289 1.08, PM 7288Q 1.15)
For double-ridge waveguide 1.20

Insertion loss: For rectangular waveguide 0.1 dB
For double-ridge waveguide 0.4 dB
0.3 for PM 7286DX and PM 7288Q

Flange face mates: For rectangular waveguide
MIL-F-3299/53 or
Type B IEC154
For double-ridge waveguide
MIL-F-39000/3

Pressurization: 0.2 MPa diff (2ATO)

Leakage: Max 50 cc/min at 0.2 MPa diff

Life: $250 \cdot 10^3$ actuations guaranteed

Material: Aluminium alloy copper-free

Finish: Chromate per MIL-C-5541A and dull black paint

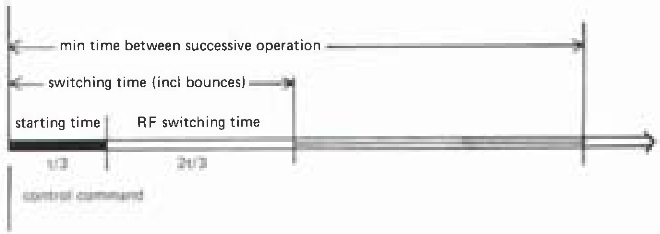
Temperature range: −40°C to +85°C operating
−70°C to +125°C storage

Manual override: SL 6706 available on PM 7286 models

Vibration: ±1.5 mm ampl 5–40 Hz
10 g acc 40–2000 Hz

Switching time: The figures given in the table are maximum values at +85°C and for minimal actuator voltage

The switching time (as defined in MIL-S-55041B, “Switches waveguide, general specifications for”) is at +25°C and nominal voltage 30–40% lower than given



Duty: 500 ms −40° to +40°C linearily increasing to 2 s at +85°C (min time between successive operations)
(2 sec rewinding time for the PM 7296-series)

Rectangular waveguide

Waveguide	Frequency range GHz	Model	Power[1] peak kW	avg kW	Isolation dB	Actuator	Switching time ms	Actuator[2),3)] pull in/ holding current A	Position indicator[4)]	Weight kg	Outline fig	Con-nector
R 14 WR 650 WG 10	1.1 – 1.7	PM 7295L[6)]										
R 32 WR 284 WG 10	2.6 – 3.95	PM 7295S	3000	4	90	manual	N/A	N/A	4)	9.5	D	—
R 32 WR 284 WG 10	2.6 – 3.95	PM 7296S[5)]	3000	4	90	latching	700	5/2[7)]	built-in	11.0	A	3
R 48 WR 187 WG 12	3.95– 5.95	PM 7296G	1000	4	90	latching	600	5/2[7)]	built in	6.5	B	3
R 48 WR 187 WG 12	3.95– 5.95	PM 7305G	1000	4	80	manual	N/A	N/A	4)	4.3	C	—
R 84 WR 112 WG 15	7.05–10.0	PM 7286H	350	4	70	latching	200	1.3	built-in	0.8	K	2
R 84 WR 112 WG 15	7.05–10.0	PM 7297H	350	4	90	failsafe	160	1.9/0.6	built-in	1.5	F	1
R 100 WR 90 WG 16	8.2 –12.4	PM7297X	250	3	90	failsafe	100	1.5/0.5	built-in	0.9	H	1
R 100 WR 90 WG 16	8.2 –12.4	PM 7286X	250	3	90	latching	200	1.3	built-in	0.8	K	2
R 100 WR 90 WG 16	8.2 –12.4	PM 7288X	250	3	60	failsafe	150	1/0.3	built-in	0.4	L	4
R 100 WR 90 WG 16	8.2 –12.4	PM 7289X	250	3	60	latching	150	1	built-in	0.4	L	4
R 100 WR 90 WG 16	8.2 –12.4	PM 7295X	250	3	90	manual	N/A	N/A	4)	0.9	M	—
R 100 WR 90 WG 16	8.2 –12.4	PM 7299X	250	3	65	latching	100	3.5	built-in	0.5	U	4
R 100 WR 90 WG 16	8.2 –12.4	PM 7305X	250	3	70	manual	N/A	N/A	4)	0.9	M	—
R 120 WR 75 WG 17	10.0 –15.0	PM 7286M	250	3	85	latching	200	1.3	built-in	0.8	K	2
R 120 WR 75 WG 17	10.0 –15.0	PM 7305M	250	3	80	manual	N/A	N/A	4)	0.9	M	—
R 140 WR 62 WG 18	12.4 –18.0	PM 7297P	125	2	90	failsafe	100	1.5/0.4	built-in	0.9	H	1
R 140 WR 62 WG 18	12.4 –18.0	PM 7286P	125	2	90	latching	200	1.3	built-in	0.8	K	2
R 140 WR 62 WG 18	12.4 –18.0	PM 7288P	125	2	60	failsafe	150	1/0.3	built-in	0.4	L	4
R 140 WR 62 WG 18	12.4 –18.0	PM 7289P	125	2	60	latching	150	1	built-in	0.4	L	4
R 140 WR 62 WG 18	12.4 –18.0	PM 7299P	125	0.5	70[8]	latching	60	3.5	built-in	0.4	V	4
R 140 WR 62 WG 18	12.4 –18.0	PM 7305P	125	2	90	manual	N/A	N/A	4)	0.9	M	
R 120 WR 28 WG 22	32.0 –36.0	PM 7288Q	20	0.1	60	failsafe	150	1/0.3	built-in	0.4	L	4

Double ridge waveguide

Waveguide	Frequency range GHz	Model	Power peak kW	avg kW	Isolation dB	Actuator	Switching time ms	Actuator current A	Position indicator	Weight kg	Outline fig	Connector
WRD 475 D 24	4.75–11.0	PM 7286DX	80	1.5	40	latching	200	1.3	built-in	0.8	P	2
DR 19	4.75–11.0	SL 6643	80	0.5	40	latching	120	1.3	built-in	0.8	Q	4
WRD 650 D 28	6.5 –18.0	SL 6645	20	0.5	40	latching	60	3.5	built-in	0.4	X	4
WRD 750 D 24	7.5 –18.0	PM 7288DP	30	0.75	40	failsafe	150	1/0.3	built-in	0.4	R	4
WRD 750 D 24	7.5 –18.0	PM 7289DP	30	0.75	40	latching	150	1	built-in	0.4	R	4
WRD 750 D 24	7.5 –18.0	PM 7304P	30	0.75	40	latching	60	3.5	built-in	0.4	X	4

1) Power capacity: at 0.1 MPa (abs) (sea level) and +25°C ref MIL-W23351/4B.

2) Actuator voltage: 28 ±3 V DC (PM 7296S and PM 7296G require 24 V DC)

3) Actuator current: value given refers to +25°C ambient temperature

4) Position indicator: built-in for most models, otherwise a separate position indicator PM 7315 is available. It can be mounted on the rotor shaft, accessible at the bottom of the switch. Outline drawing T. Max power rating 60 V/500 mA resistive load. Min power rating 4 V/10 mA resistive load 100 mA for PM 7297.

5) PM 7296S has NATO stock no 5840-99-945-8243.

6) See "Tailor made products"

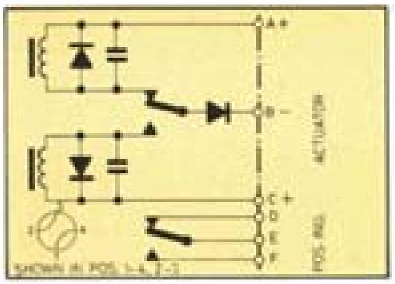
7) Starting current/operating current

8) 17-18 GHz; 60 dB

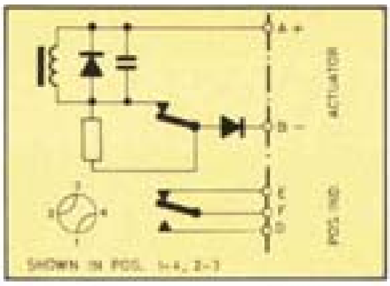
Connectors	Mating cable connectors (to be ordered separately)	
1. KPT 07H 10-6P	KPT 06E 10-6S	SL 80376
2. KPT 07C 10-6P	KPT 06E 10-6S	SL 80376
3. MS 3102 E14S-5P	MS 3106 E14S-5S	SL 80610
4. Soldering pins		

Waveguide switches

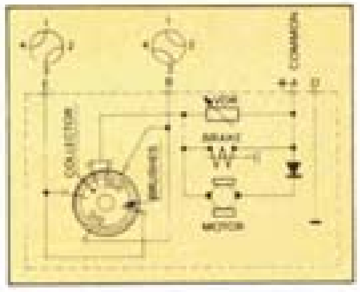
Circuit diagram



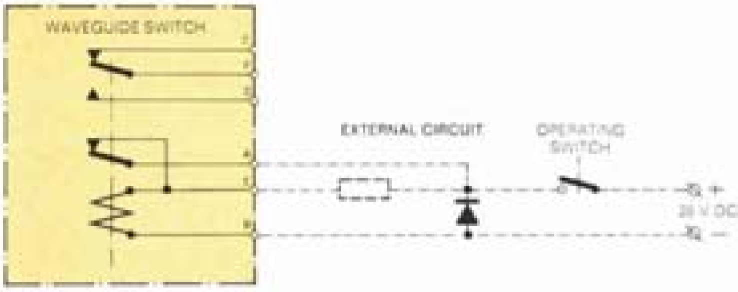
PM 7286
PM 7289



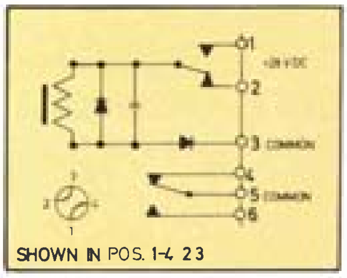
PM 7288



PM 7296 +24 V to common

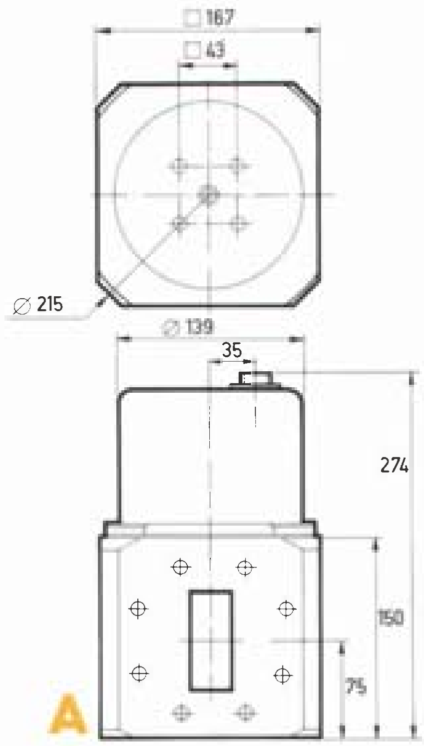


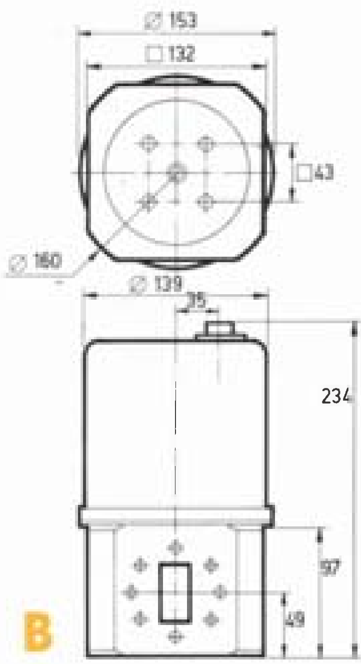
PM 7297

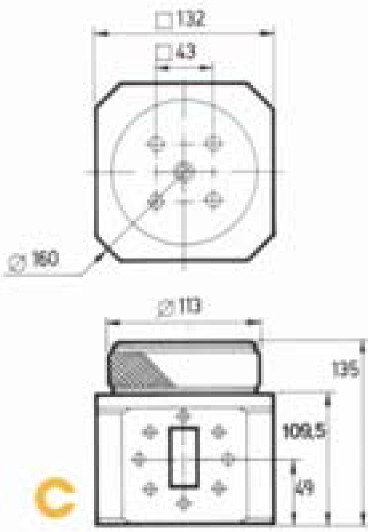


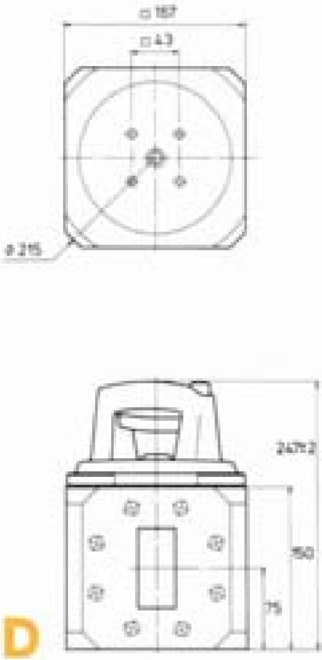
PM 7299
PM 7304
SL 6645

Outline drawings

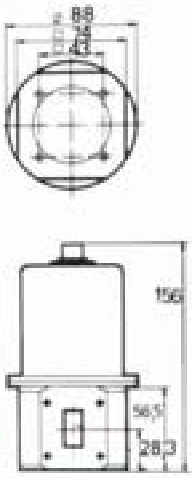




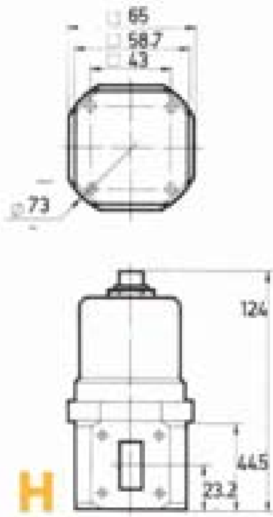



□ 157
□ 43
ø 215
247±2
150
75

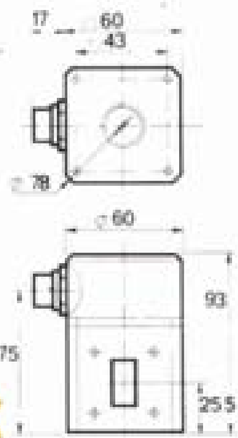
D


ø 88
□ 74
□ 43
156
56.5
28.3

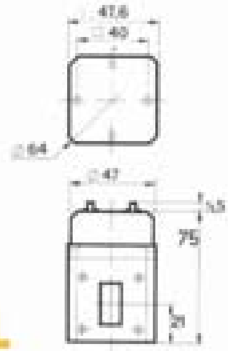
F


□ 65
□ 58.7
□ 43
ø 73
124
44.5
23.2

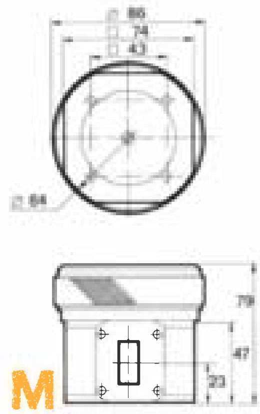
H


17
60
43
ø 78
ø 60
93
75
25.5

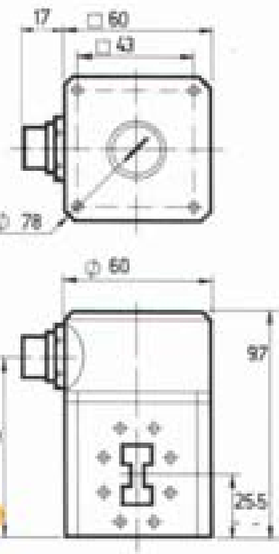
K


47.6
□ 40
ø 64
ø 47
5.5
75
21

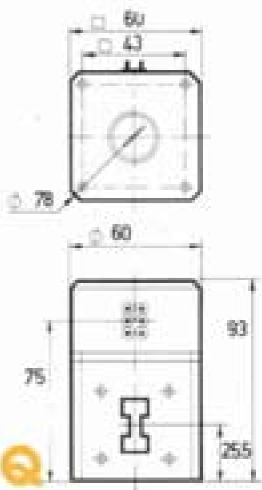
L


ø 88
□ 74
□ 43
ø 84
79
47
23

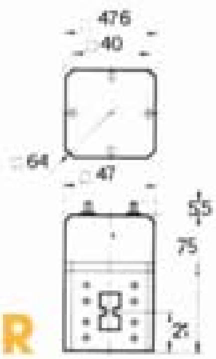
M


17
□ 60
□ 43
ø 78
ø 60
97
79
25.5

P

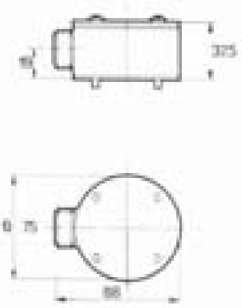

□ 60
□ 43
ø 78
ø 60
93
75
25.5

Q

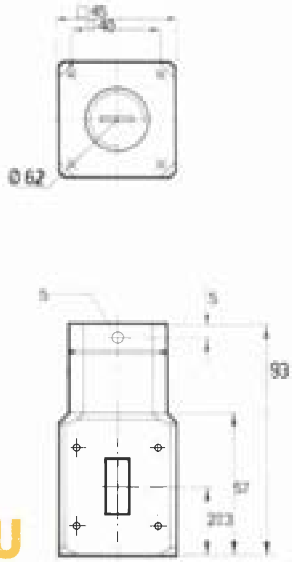

47.6
40
64
47
5.5
75
21

R

Waveguide switches



T



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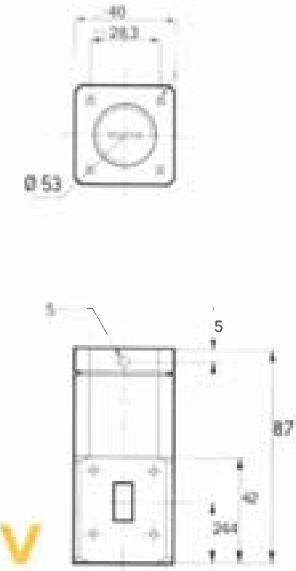
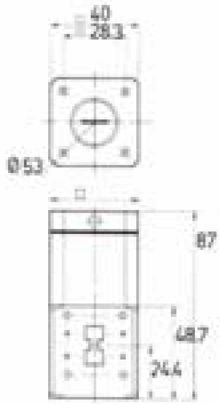


V



X

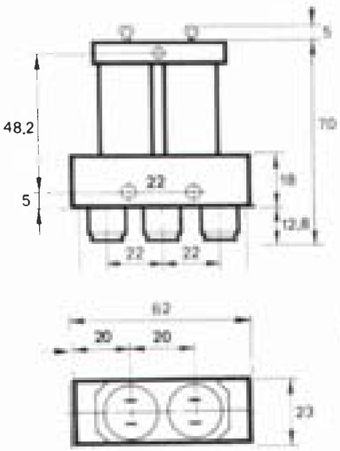
Medium power model 7535

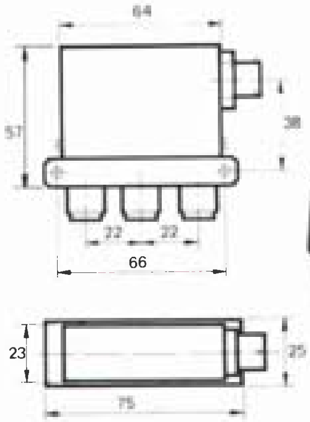
This coaxial switch uses blade type contacts for high switching speed and long operational life. The contact blades are integrated in a coaxial structure to assure perfect match over a large frequency range. The solenoids have separate connections which can be used to arrange for different break-make time diagrams. When the solenoids are shunt-connected the contacts will operate in a break-before-make mode.

High power model PM 7540

The high power coaxial SPDT PM 7540 has a design with excellent thermal conduction between the centre conductor and housing to enable high power operation. This is achieved by using special thermoconductive materials as dielectric.

The actuator is failsafe and the RF-contact operate in a break-before-make model.





Specification, both models, DC-12.4 GHz

Frequency	DC-1 GHz	1–7 GHz	7–12.4 GHz
VSWR	<1.10	<1.35	<1.50
Insertion loss	<0.2	<0.3	<0.5
Isolation	>70	>65	>60

RF Impedance 50 Ω

Max. RF power:[1] PM 7535 peak 10 kW,[2]
average 50 W at 12.4 GHz
PM 7540 peak 10 kW,[2]
average 1 kW at 1 GHz
300 W at 10 GHz

See also diagram.

[1] Under steady-state condition, switching RF power will damage the components.

[2] At +25°C, 0.1 MPa (sea level).

[3] Maximum value at +25°C, nominal voltage.

Model	PM 7535	PM 7540
Switch. function	SPDT	SPDT
Actuator	failsafe	failsafe
Switching time	25 ms	100 ms
Pull-in/holding current[3]	220/220 mA	220/220 mA
Position indicator	no	yes
Terminals	solder pins	connector PT07-10-6P cable connector PT07-10-6S can be ordered separately
Weight	250 g	350 g
Actuator voltage	28 ±3 V DC	28 +2/–8 VDC

Temperature: –55°C to +85°C ambient

RF connectors: N-type jack per MIL 39012

Life: min 10^6 actuations guaranteed

Material: RF-connectors stainless steel
RF-circuit: aluminium (chromated)
beryllium copper, gold plated

Finish: dull black paint, epoxy

Vibration: (PM 7540) sine 5–40 Hz, amplitude 1.5 mm
sine 40–2000 Hz, acceleration 10 g
(PM 7535) sine 20–60 Hz, amplitude 0.35 mm
sine 60–2000 Hz, acceleration 5 g

Coaxial switches, SMA

General

The light weight coaxial switches of the PM 7550-series are designed for use in wideband miniaturized microwave systems under severe environmental conditions. Advanced stripline technique provides excellent electrical performance up to 18 GHz.

Latching or failsafe

Latching models require no holding current, whereas the **failsafe** models have a small holding current. Switching is break-before-make.

Protection circuit

Means for supply line interference suppression and reversed polarity protection are incorporated in most models.

Environmental

The switches are desigend to be used in equipment, that meets MIL-E-5400 and MIL-E-16400. A balanced actuator construction having a small mass ensures that the switches withstand shock/vibrations.

Position indicator

For remote indication of the switch position additional contacts are incorporated, in most models.

Mounting

The switches are provided with mounting holes which also enable easy stacking of several units. This facilitates more complicated switching configurations (matrixing). Min. distance between adjacent switches is 5 mm for latching models, 10 mm for failsafe models.

Specification DC-18 GHz, all models

Frequency	DC–1 GHz	1–4 GHz	4–12 GHz	12–18 GHz
VSWR	<1.10	<1.20	<1.35	<1.50
Insertion loss	<0.1 dB	<0.2 dB	<0.3 dB	<0.5 dB
Isolation[3]	>80 dB	>70 dB	>65 dB	>60 dB

RF impedance:	50Ω
Max. RF power:[1]	peak 1 kW, average 15 W
Actuator voltage:[5]	28 ±5 V DC
Duty cycle:	PM 7550-53 50 ms –55°C – +40°C lineary increasing to 200 ms at +85°C (min. time between succesive operations) PM 7555-57 100%
Temperature:	–55°C to +85°C ambient
RF connectors:	SMA jack per MIL-39012
Life:	min. 10^6 actuations guaranteed
Vibration:	Sine ±1.5 mm, 5–60 Hz Sine 20 g, 60–2000 Hz
Material:	RF-house: aluminium RF-connectors: stainless steel, gold plate beryllium-copper terminals: soldering pins
Finish:	dull black paint

[1] Under steady-state condition, switching RF power will damage the components.

Reliability–100% testing

All switches pass an extensive screening procedure, where all circuit parameters are checked across the frequency range, and continuous operation (running-in more than 5,000 actuations)is checked during temperature cycling. This enables the detection of early and intermittent failures.

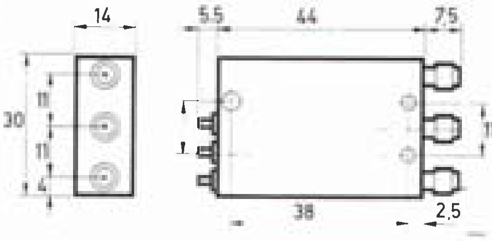
Model	**PM 7550**	**PM 7551**	**PM 7552**	**PM 7553**	**PM 7555**	**PM 7555/01**	**PM 7557**	**PM 7557/01**	**PM 7560**	**PM 7561**
Switch function	SPDT	Transfer	SPDT	Transfer	SPDT	SPDT	SPDT	SPDT	SPDT	Transfer
Actuator	latching	latching	failsafe	failsafe	latching	latching	failsafe	failsafe	manual	manual
Switching time	15 ms	15 ms	15 ms	15 ms	20 ms	20 ms	20 ms	20 ms	n/a	n/a
Pull-in/holding current at 25°C max.	350/-mA	350/-mA	440/40 mA	400/40 mA	60/-mA	60/-mA	60/60 mA	60/60 mA	n/a	n/a
Position indicator	yes	yes	yes	yes	no	yes	no	yes	no	no
Self cut-off	yes	yes	n/a	n/a	yes	no[4]	n/a	n/a	n/a	n/a
Weight[2] max.	65 g	85 g	65 g	85 g	55 g	55 g	55 g	55 g	35 g	60 g

[2] 1 oz equals 28.35 g.
[3] Up to 90 dB available on option.
[4] Recommended pulse width 20–30 ms.

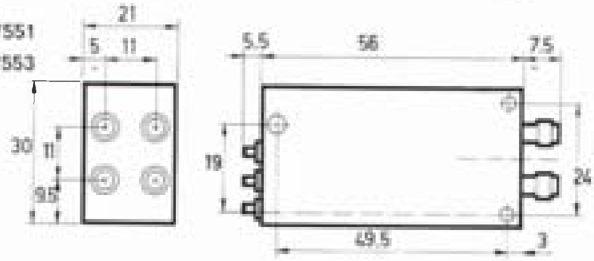
[4] Recommended pulse width 20–30 ms.
[5] 12 V DC available for PM 7555 and PM 7557.

Outline drawing

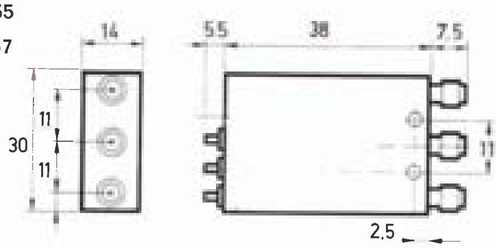
PM 7550
PM 7552



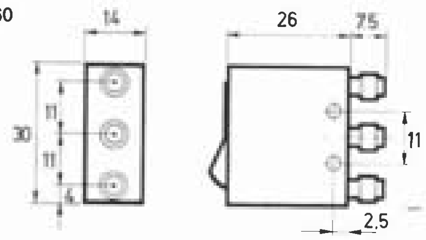
PM 7551
PM 7553



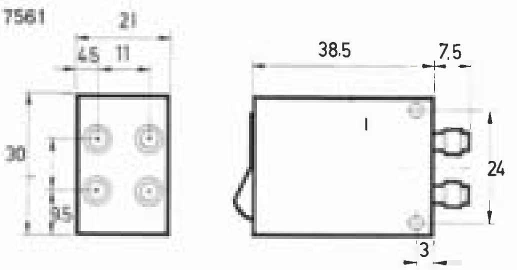
PM 7555
PM 7557



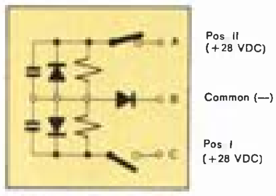
PM 7560



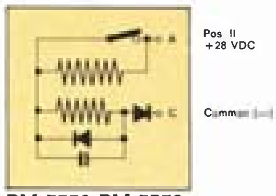
PM 7561



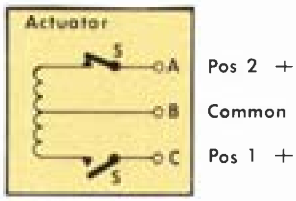
Actuators



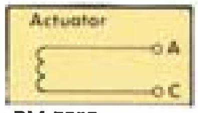
PM 7550 PM 7551



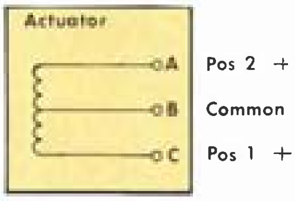
PM 7552 PM 7553



PM 7555

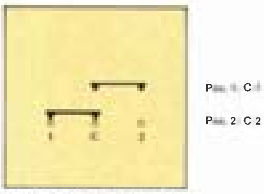


PM 7557
PM 7557/01

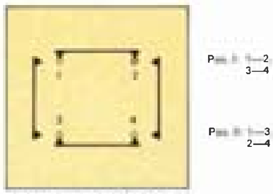


PM 7555/01

RF circuits

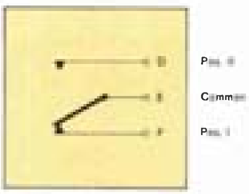


PM 7550 PM 7552
PM 7555 PM 7557
PM 7560



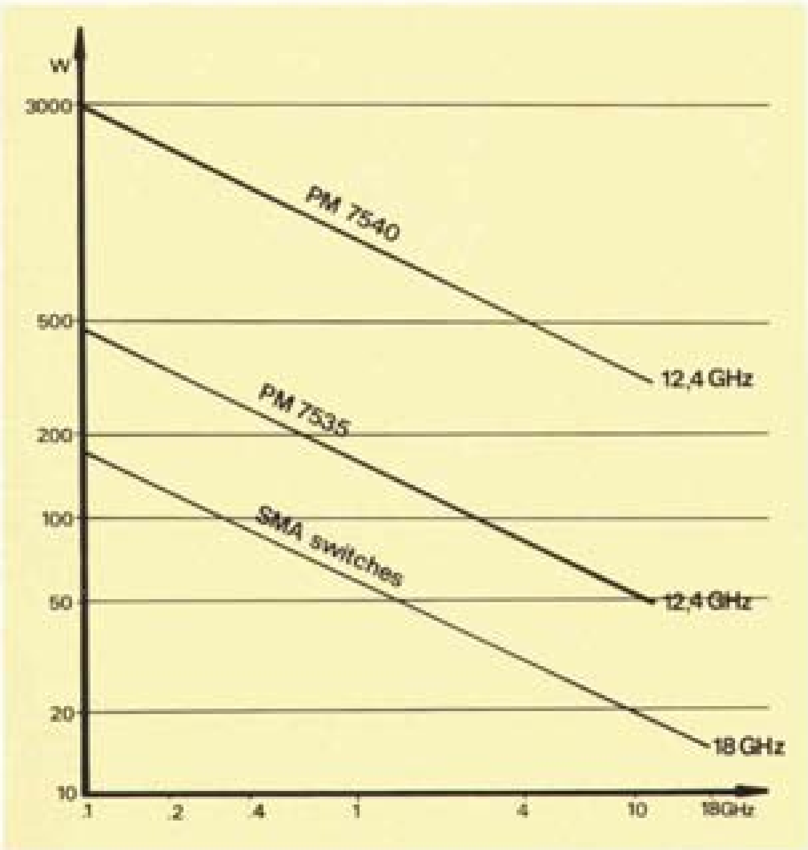
PM 7551 PM 7553
PM 7561

Position indicators



PM 7550 PM 7551
PM 7552 PM 7553
PM 7555/01
PM 7557/01

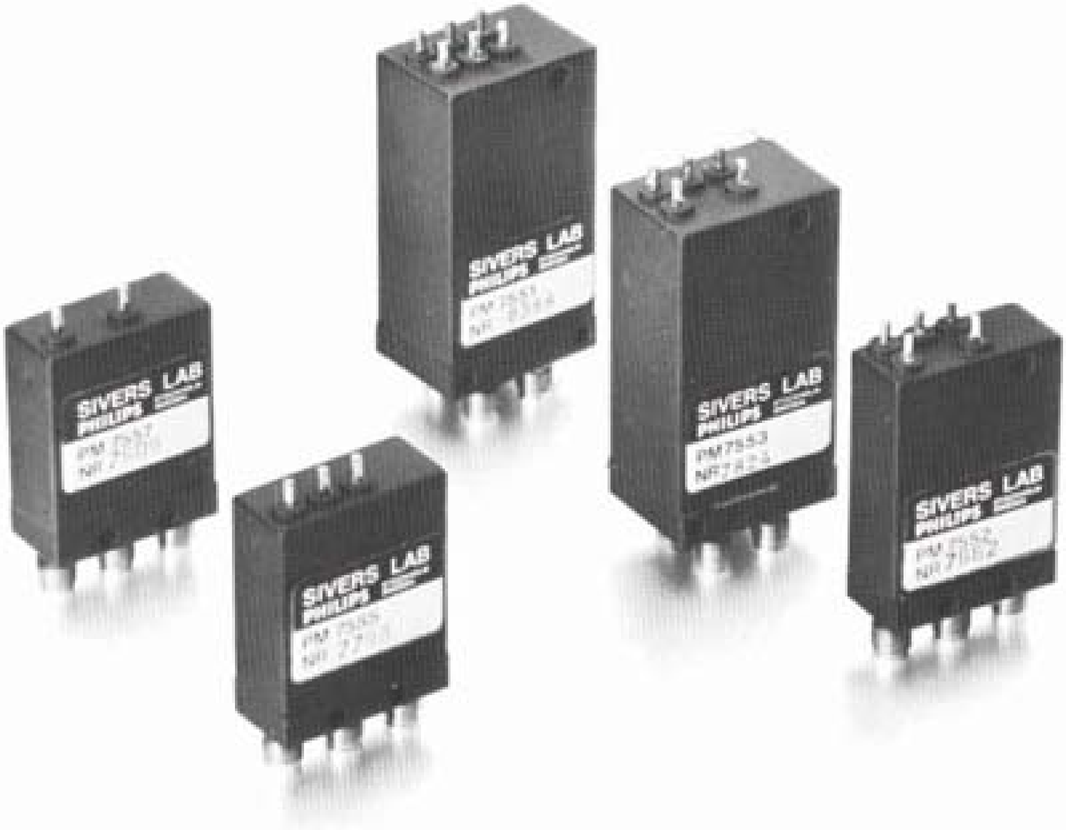
Power handling



Average power capacity

Max. RF-power at +85°C, load VSWR = 1:1

Coaxial switches, SMA



Rotary joints

Rotary joints

A vital part of a radar antenna system is the rotary joint, linking together the stationary part with the rotating part of the radar. The rotary joint must be capable of transmitting high microwave power with a minimum of losses while it is rotating, often at a high speed and in severe environments. Whatever the application is, SIVERS IMA probably have the rotary joint you need.

Our product range today, covers Single and Multichannel Joints, Waveguide with high power capacity, and Coaxial, from DC up to 40 GHz, Capacitive and Contacting. Integral Slip-ring options, Stackable and Around the Mast.

A few examples:

Application	Solution
SSR/IFF	3-ch coax
ATCR	2 waveguide + 4 coax
Airborne radar	2 waveguide
ESM	3-ch coax
Jammer	1 waveguide + 1 coax
Fire control	2 waveguide +1 coax
Surveillance radar	1 waveguide + 2 coax

1. Six channel rotary joint SL 6768L/2
2. S-band U-type rotary joint PM 7364S
3. Around the mast coaxial rotary joint SL 6787
4. Two channel contacting rotary joint SL 6758
5. Double ridge rotary joint PM 7364DP
6. One channel WG rotary joint PM 7360P
7. Coaxial rotary joint DC-40 GHz PM 7889

General description

The part of a rotary joint which is containing the very joint must be electrically symmetrical. To achieve broad bandwidths, unwanted modes must be supressed. Our solution for this, which applies for most rotary joints in this catalog, is to use a coaxial line carrying the symmetrical TEM-mode. A waveguide rotary joint is then achieved by means of coaxial to waveguide transitions. Some advantages with this solution are:

- high power handling capacity
- broad bandwidth
- different configurations are possible
- multi-channel joints can be realized

In a coaxial joint electrical continuity is maintained by the use of spring contacts or by $\lambda/4$ chokes.

Precious metal contacts extend the useful frequency range from the cutoff-frequency down to DC. Very compact designs are possible.

Quarter wave chokes require more space but have advantages such as long life, due to the absence of mechanical wear in the microwave circuit and simplicity.

All rotary joints in this catalog are ball-bearing supported. By a sort of preloading, the play of the ball-bearing is eliminated, which gives a very good centering and small gaps. Additionally, a proper lubrication reduces the torque.

Most joints are provided with seals to enable pressurization. Leakage test is performed at 0.2 MPa (2 ATO) overpressure. The leakage rate must not exceed 25 cc/min.

All SIVERS IMA rotary joints are fully tested before shipment and electrical performance is certified in writing.

Rotary joint configurations

The following configurations are possible:

U-style: Two right-angle arms, one fixed to the housing. One free to rotate.
Advantages – About 50 percent higher peak power capacity than other configurations
Additional channels can easily be provided by using a hollow centre conductor.

I-style: Two in-line arns, one fixed to the housing. One free to rotate.
Advantages – Higher average power capacity than the U-style.

F-style One in-line arm fixed to the housing, one right-angle arm free to rotate.

L-style: One right-angle arm fixed to the hosing, one in line arm free to rotate.

Additional channels

Dual-channel: Two mechanically concentric, electrically isolated transmission lines designed to maintain electrical continuity for two signal paths under conditions of simultaneous mechanical rotation, with minimum cross-talk.

Multi-channel: Rotary joints with three or more concentric, electrically isolated transmission lines.

Definitions

Life: The life of a rotary joint depends on many factors, e g temperature, speed, gas pressure, mechanical loading conditions. For most rotary joints 50 million revolutions are guaranteed without maintenance.

Speed: The max rotational speeds are ranging from 5 rpm for pressurized L-band waveguide rotary joints to 2000 rpm for unpressurized coaxial rotary joints.

WOW: Rotational phase effects are negligible for all models. The variation of VSWR during rotation, the WOW, is defined as

$$\text{WOW} = \frac{\text{VSWR max}}{\text{VSWR min}}$$

Starting torque: Max starting torque (Nm) over the whole temperature range and at maximum specified pressure.
(1 Nm = 0.101972 kpm = 0.737562 ft · lbf)

Pressurization: Maximum permitted pressurization in atmosphere overpressure (ATO), or in megapascal difference (MPa diff).

Temperature: The rotary joints are designed for operating temperature range −40 to +85°C, and storage range of −70 to +125°C. Other temperature ranges require special seals and lubrication.

Power: The power capacity of the rotary joints is dependent on many factors, e g temperature, pressure, spurious and harmonic power, pulse length, repetition rate. Their relative influence is indicated on the chart on page 58.

Care must be taken not to use these data over too wide a range. For instance, the relationship between breakdown power of the waveguide and the pressure may change drastically if transition from volume breakdown to local breakdown occurs.

The figures of power capacity given in the tables are valid for +25°C, 0.1 MPa abs (1 ATA), 2 μs pulsewidth, 500 Hz repetition rate and matched load.

Isolation: Isolation between channels is normally 50 dB.

Slip-rings

The turnable of a radar antenna is not only used for microwave transmission but often also for various transmissions and control demands, e.g. antenna alignment. SIVERS IMA work close together with a leading European slip-ring manufactor and thus can offer complete packages with built-in slip-rings.

The slip-ring package can be from a few rings built-in into the rotary joint to multi-slip-rings outside the joint. Common for all solutions are that the dimensions of the turntable may be reduced and that the electrical and microwave transmission of the turntable is integrated into one package. Another advantage is that when integrating the complete electrical/microwave-transmission into one package a reconstruction of the turntable is not always necessary when the whole system is to be refurbished.

The slip-rings can be conventional DC or AC rings for high currents or shielded high frequency rings for frequencies up to 300 MHz. Under development is also optical multi-channel slip-rings.

The slip-rings are mostly customer specified. On this page we show some examples of units delivered and we welcome your enquiries.

A three channel rotary joint with integrated 8-ways slip-ring package.

This picture shows a small selection of our range of standard slipring assemblies.
At the left side in front a 6-way module with av separate brush block is shown, to the right you see a 12-way slipring module and behind this a 3-way disc or pancake slipring is shown.

An example of a 3 channel rotary joint with integrated slip-ring package – SL 68 01X. The specification for the slip-ring unit shown is:

Number of channels	16 ways (isolated) 0.5 A, 26 V, 400 Hz or 0.5 A, 28 V, DC
Electrical noise:	Max 50 μV/mA under following conditions: a) current 20 mA $\pm$5 mA b) frequency band Dc to 1 Hz rotational speed max 150 rpm
Insulation resistance:	100 MΩ at 500 VDC
Operational life:	10.000 hours at 60 rpm

Waveguide rotary joints

Single-channel

The rotary joints described below are standard designs, but they are usually not stocks items. Our complete rotary program consists of several more, most of them customer specified, and we welcome your enquiries.

Waveguide size	Frequency range GHz	Model	Flanges[2] mate	Power[1] peak kW	Power[1] avg kW	VSWR	WOW
I-Style							
R 14 WR 650 WG 6	1.15– 1.45	**PM 7360L**	PDR 14	6000	30	1.15	1.02
R 32 WR 284 WG 10	2.7 – 3.4	**PM 7360S**	UAR 32	1000	7.5	1.20	1.02
R 58 WR 159 WG 13	5.9 – 6.4	**PM 7360C**	PDR 58	200	5	1.15	1.02
R 84 WR 112 WG 15	8.5 – 9.6	**PM 7360H**	UG-138/U	200	2	1.15	1.02
R 100 WR 90 WG 16	8.5 – 9.6	**PM 7360X**	UG-135/U	100	1	1.10	1.02
R100 WR 90 WG 16	8.2 –11.0	**PM 7373X**	UG-135/U	100	1	1.30	1.03
R 120 WR 75 WG 17	10.95–14.5	**PM 7373M**	UBR 120	30	0.5	1.50	1.03
R 140 WR 62 WG 18	12.4 –18.0	**PM 7373P**	UBR 140	15	0.2	1.60	1.05
R 140 WR 62 WG 18	15.5 –17.5	**PM 7360P**	UBR 140	30	0.5	1.15	1.03
L-Style							
R32 WR 284 WG 10	2.7–3.3	**PM 7362S**	UAR 32	1000	5	1.20	1.02
R 48 WR 187	5.4–5.9	**PM 7362G**	UAR 48	400	2	1.15	1.02
R58 WR 159 WG 13	5.4 – 5.9	**SL 6791C**	PDR 58/spec	90	2	1.15	1.05
R 84 WR 112 WG 15	8.5 – 9.6	**PM 7362H**	UG-138/U	200	1	1.15	1.02
WR 102	7.2 –10.8	**PM 7362T**	UG-1493/U	50	0.75	1.30	1.03
R 100 WR 90 WG 16	8.5 – 9.6	**PM 7362X**	UG-135/U	100	0.5	1.15	1.02
R 100 WR 90 WG 16	9.0 – 9.5	**PM 7887X**	UG-135/U	75	0.5	1.10	1.02
R 140 WR 62 WG 18	16.0 –17.0	**PM 7362P**	UBR 140	30	0.5	1.15	1.03
F-Style							
R 84 WR 112 WG 15	8.5 – 9.6	**PM 7897H**	UBR 135/U	200	1	1.15	1.02
WRD 750 D 24	7.5 –17.5	**PM 7897DP**	M 39000/3-072	20	0.35	1.50	1.05
U-Style							
R 14 WR 650 WG 16	1.25– 1.35	**PM 7364L**	UG-418A/U	3000	6	1.20	1.05
R 32 WR 284 WG 10	2.7 – 3.3	**PM 7364S**	UAR 32	1500	5	1.15	1.02
R 48 WR 187 WG 12	5.4 – 5.9	**PM 7364G**	UAR 48	700	3	1.15	1.02
R 84 WR 112 WG 15	8.5 – 9.6	**PM 7364H**	UG-138/U	250	1	1.10	1.02
WR 102	7.2 –10.8	**PM 7364T**	UG-1493/U	50	0.75	1.40	1.05
R 100 WR 90 WG 16	8.5 – 9.6	**PM 7364X**	UG-135/U	150	0.5	1.10	1.02
R 100 WR 90 WG 16	8.2 –12.4	**PM 7371X**	UG-135/U	75	0.5	1.30	1.03
R 140 WR 62 WG 18	14.0 –17.5	**PM 7364P**	UBR 140	60	0.3	1.15	1.04
WRD 475 D 24	4.75–10.8	**PM 7364 DX**	M 39000/3-36	30	0.7	1.50	1.05
WRD 750 D 24	7.5 –17.5	**PM 7364 DP**	M 39000/3-072	20	0.35	1.50	1.05

Fininsh: Chromate per MIL-C-5541A and dull black paint for aluminium Silver and dull black paint for brass

Pressurization: 0.2 MPa diff (2 ATA)

Leakage: max 25 cc/min at 0.2 MPa diff (2 ATA)

Temperature range: –40°C to + 85°C operating; –70°C to +125°C storage

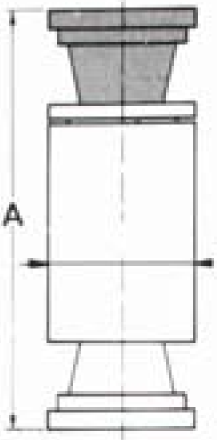
Life: 10–50 · 10^6 revolutions guaranteed (depending on model)

Waveguide rotary joints

Insertion loss dB max	Starting torque Nm max	Material	Weight kg	Dimensions in mm A	B	C
0.1	5	Al	40	1000	220	–
0.1	1	Al	8.0	462	144	–
0.15	0.3	Al	1.4	163	85	–
0.15	0.4	Al	0.6	140	48	–
0.2	0.4	Al	0.3	76.5	45	–
0.25	0.4	Al	0.3	76.5	45	–
0.3	0.3	Al	0.3	76.5	45	–
0.5	0.1	Brass	0.55	76.2	46	–
0.15	0.1	Brass	0.55	76.2	46	–
0.15	1	Al	7.0	326	105	110
0.1	1.5	Al	2.5	120	95	70
0.2	0.4	Al	0.8	106	55	90
0.15	0.4	Al	0.6	106	48	40
0.3	0.3	Al	0.6	118	47	70
0.15	0.4	Al	0.3	60.7	45	39
0.20	0.3	Brass	0.6	74.5	46	35
0.25	0.1	Al	0.2	56	38	30
0.15	0.4	Al	0.6	123	48	40
0.50	0.3	Al	0.25	65	40	50
0.3	3	Al	–	700	165	150
0.15	1	Al	6.7	192	105	110
0.1	0.4	Al	2	130	75	70
0.15	0.4	Al	0.6	89	48	40
0.5	0.3	Al	0.8	50	46	52
0.15	0.4	Al	0.3	44.5	45	39
0.2	0.4	Al	0.3	49	45	47
0.25	0.1	Al	0.2	41	38	30
0.5	0.4	Al	0.6	50	45	50
0.5	0.3	Al	0.25	45	40	50

[1] The power capacity of rotary joints are given for +25°C 0.1 MPa (1 ATA) 2 μs pulsewidth, 500 Hz repetition rate and matched load.

[2] Flange face conforms to MIL-F-3922 or IEC 154 Type B. For double-ridge waveguides MIL-F-39000.



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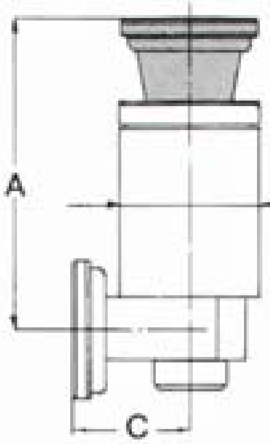

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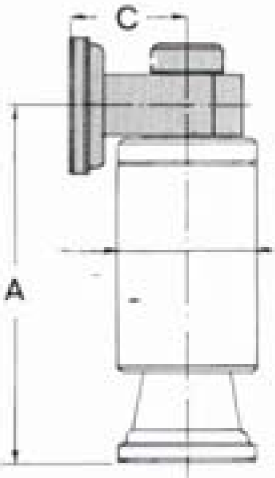
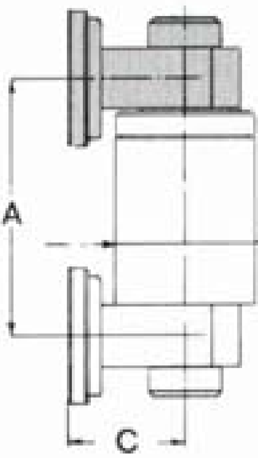


F-Style



U-Style

Waveguide rotary joints

Dual-channel

The rotary joints described below are standard designs, but they are usually not stocks items. Our complete rotary program consists of several more, most of them customer specified, and we welcome your enquiries.

Channel no	Style	Waveguide/coax size	Frequency range GHz	Model	Flange/[2] conn mates	Power[1] peak kW	Power[1] average kW	VSWR max	WOW in VSWR
1	I	**R 14 WR 650 WG 6**	1.15– 1.45	**PM 7361L**	PDR 14	6000	30	1.15	1.02
2		**7/8 EIA**	1.5 – 2.0		7/8 EIA	10	0.5	1.35	1.05
1	L	**R 32 WR 284 WG 10**	2.7 – 3.3	**PM 7363S**	UAR 32	1000	5.0	1.20	1.02
2		**N-type coax**	1.0 – 1.1		N	5	0.2	1.2	1.03
1	U	**R 32 WR 284 WG 10**	2.7 – 3.3	**PM 7896S**	UAR 32	1500	5.0	1.15	1.02
2		**N-type coax**	1.0 – 1.1		N	5	0.2	1.30	1.03
1	U	**R 32 WR 284 WG 10**	2.7 – 3.0	**SL 6765S**	5985-99-083-0058	300	5.9	1.15	1.02
2		**N-type coax**	1.1 – 1.3		N	7.5	8.25 W	1.2	1.02
1	U	**R 32 WR 284 WG 10**	2.7 – 3.1	**SL 6785S**	5985-99-083-1560	1500	5	1.15	1.03
2		**N-type coax**	2.7 – 3.1			–	10 W	1.3	1.05
1	U	**R 48 WR 187 WG 12**	5.4 – 5.9	**PM 7896G**	UAR 84	700	3	1.15	1.02
2		**N-type coax**	0.9 – 1.2		N	5	0.25	1.20	1.03
1	U	**R 48 WR 187 WG 12**	5.25– 5.8	**SL 6753G**	UAR 48	700	3	1.15	1.03
2		**N-type coax**	1.6 – 1.8		N	5	0.25	1.20	1.05
1	L	**R 58 WR 159 WG 13**	5.4 – 5.9	**SL 6792C**	PDR/mod	90	2	1.15	1.05
2		**SMA/TNC coax**	1.6 – 1.9		SMA/TNC	1.5	5 W	1.3	1.05
1	U	**R 84 WR 112 WG 15**	8.4 – 9.6	**PM 7896H**	UG-138/U	250	1.0	1.10	1.02
2		**SMA coax**	1.0 – 1.1		SMA	5	0.25	1.20	1.05
1	U	**R 84 WR 112 WG 15**	8.5 – 9.6	**PM 7896H/01**	UG-138/U	250	1.0	1.10	1.03
2		**N-type coax**	8.5 – 9.6		N	5	0.3	1.50	1.05
1	U	**R 100 WR 90 WG 16**	8.2 –12.4	**PM 7371X/02**	UG-135/U	75	0.5	1.30	1.03
2		**SMA coax**	8.2 –12.4		SMA	1.0	50 W	1.50	1.05
1	U	**R 100 WR 90 WG 16**	8.5 – 9.6	**PM 7896X**	UG-135/U	150	0.5	1.10	1.03
2		**SMA coax**	1.0 – 1.1		SMA	5	0.2	1.30	1.05
1	U	**R 100 WR 90 WG 16**	8.5 – 9.6	**PM 7896X/01**	UG-135/U	150	0.5	1.10	1.03
2		**N-type coax**	8.5 – 9.6		N	5	0.2	1.50	1.05
1	U	**R 100 WR 90 WG 16**	8.8 – 9.3	**SL 6764X**	UBR 100/M4	100	0.1	1.20	1.03
2		**R 100 WR 90 WG 16**	8.8 – 9.3		UBR 100/M4	100	0.1	1.20	1.03
1	U	**R 140 WR 62 WG 18**	14.0 –17.5	**PM 7896P**	UBR 100	60	0.3	1.15	1.04
2		**SMA coax**	1.0 – 1.1		SMA	5	0.2	1.20	1.05
1	U	**R 140 WR 62 WG 18**	12.0 –18.0	**PM 7896P/01**	UG-419/U	60	0.2	*2.0/1.50	1.05
2		**SMA coax**	1.0 –12.0		SMA	0.5	0.2	1.5	1.06
1	U	**R 140 WR 62 WG 18**	16.0 –18.0	**PM 7896P/04**	M 3922/53-006	10	1	1.20	1.04
2		**SMA coax**	16.0 –18.0		SMA	1 W	–	1.60	1.05
1	U	**WRD 475 D 24**	4.75–10.8	**PM 7896DX**	M 39000/3-36	30	0.7	1.5	1.05
2		**SMA coax**	DC-11		SMA	5	50 W	1.5	1.05
1	U	**WRD 750 D 24**	7.5 –17.5	**PM 7896DP**	M 39000/3-072	20	0.35	1.50	1.05
2		**SMA coax**	DC-18.0		SMA	1	25 W	1.8	1.05

Finish: Chromate per MIL-C-5541A and dull black paint for aluminium Silver and dull black paint for brass

Pressurization: 0.2 MPa diff (2 ATA)

Leakage: max 25 cc/min at 0.2 MPa diff (2 ATA)

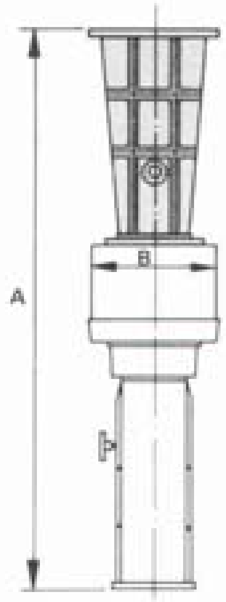
Temperature range: –40°C to + 85°C operating
–70°C to +125°C storage

Life: 10–50 · 10^6 revolutions guaranteed (depending on model)

* VSWR 2.0 for 12.0–12.4 GHz
1.5 for 12.4–18 GHz

Waveguide rotary joints

Insertion loss dB max	Starting torque Nm	Material	Weight kg	Dimensions in mm A	B	C
0.1 0.5	5	Al	41.0	1000	220	–
0.15 0.5	1	Al	7.3	326	105	110
0.15 0.5	1	Al	7.0	192	105	110
0.15 0.5	5	Al	5.0	141	109	109
0.2 0.5	1	Al	8.2	192	105	115
0.10 0.5	0.6	Al	2.2	130	75	70
0.15 0.5	0.3	Brass	8.5	120	75	147
0.2 0.3	1.5	Al	0.9	115	55	84
0.15 0.5	0.4	Al	0.65	89	48	40
0.15 0.5	0.4	Al	0.8	89	48	40
0.2 1.0	0.4	Al	0.4	49	45	47
0.15 0.6	0.4	Al	0.35	44	45	39
0.15 0.6	0.4	Al	0.35	44	45	39
0.35 0.35	0.5	Al	3.5	315	62	89
0.25 0.5	0.2	Al	0.25	41	38	30
0.7 0.7	0.2	Al	0.25	41	38	30
0.25 0.8	0.2	Al	0.25	41	38	30
0.5 1.0	0.4	Al	0.65	50	45	50
0.5 1.5	0.4	Al	0.35	45	40	50



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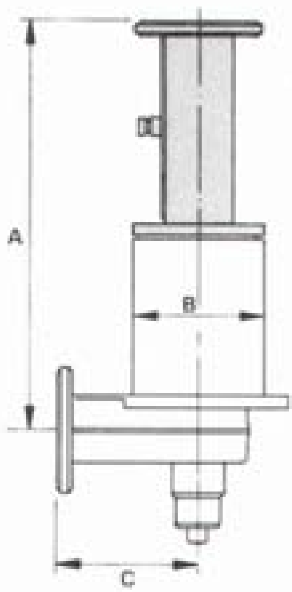

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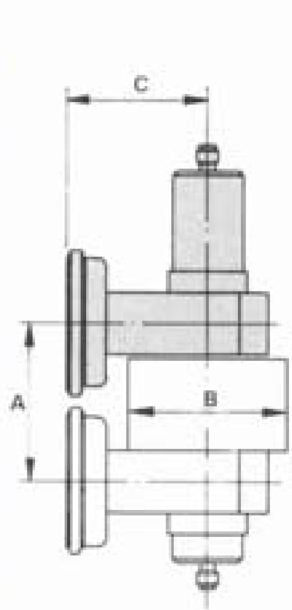
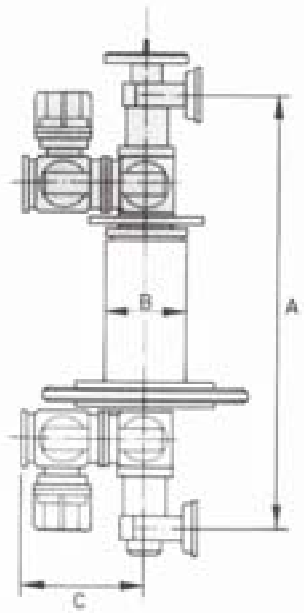


U-Style



SL 6764X

[1] The power capacity of rotary joints are given for +25°C 0.1 MPa (1 ATA) 2 μs pulsewidth, 500 Hz repetition rate and matched

[2] Flange face conforms to MIL-F-3922 or IEC 154 Type B. For double-ridge waveguides MIL-F-39000.

Waveguide rotary joints

Multi-channel

The rotary joints described below are standard designs, but they are usually not stocks items. Our complete rotary program consists of several more, most of them customer specified, and we welcome your enquiries.

Channel no.	Style		Frequency range GHz	Model	Power[1] peak kW	avg kW	VSWR max	WOW max (VSWR)	Insertion loss dB max	Starting torque Nm	Material	Weight kg
1	I	R 14 WR 650 WG 6	1.15– 1.45	PM 7899L	6000	30	1.15	1.02	0.1	5	Al	41
2		7/8 EIA	1.5 – 2.0		10	0.5	1.35	1.05	0.5			
3		N-type	DC – 2		1	0.1	2.0	1.05	0.5			
1	U	R 14 WR 650 WG 6	1.25– 1.35	SL 6768L/01	3000	6	1.20	1.05	0.3	5	Al	63
2		R 14 WR 650 WG 6	1.25– 1.35		250	0.25	1.20	1.05	0.5			
3		N-type	1.0 – 1.15		6	6 W	1.30	1.10	1.2			
4		N-type	1.0 – 1.15		6	6 W	1.30	1.10	1.2			
5		N-type	1.25– 1.35		10	20 W	1.30	1.05	1.0			
1	U	R 14 WR 650 WG 6	1.25– 1.35	SL 6768L/02	6000	12	1.20	1.05	0.3	5	AL	65
2		R 14 WR 650 WG 6	1.25– 1.35		250	3	1.20	1.05	0.3			
3		N-type	1.0 – 1.15		10	20 W	1.30	1.10	1.0			
4		N-type	1.0 – 1.15		10	20 W	1.30	1.08	1.1			
5		N-type	1.0 – 1.15		10	20 W	1.30	1.08	1.1			
6		N-type	1.25– 1.35		10	20 W	1.30	1.05	1.0			
1	U	R 14 WR 650 WG 6	1.25– 1.35	SL 6797L[2]	5000	10	1.20	1.05	0.2	5	Al	65 appr
2		N-type	1.25– 1.35		RX	RX	1.20	1.05	0.7			
3		N-type	0.9 – 1.1		5	5 W	1.30	1.08	0.8			
4		N-type	0.9 – 1.1		5	5 W	1.30	1.08	0.8			
5		N-type	0.9 – 1.1		5	5 W	1.30	1.08	0.8			
1	U	R 32 WR 284 WG 10	2.7 – 2.9	SL 6728S	1000	5	1.20	1.03	0.2	2	Al	10.5
2		HN (UG 60B/U)	1.0 – 1.12		5	0.1	1.30	1.05	0.5			
3		HN (UG 60B/U)	1.0 – 1.12		5	0.1	1.30	1.05	0.5			
1	U	R 32 WR 284 WG 10	3.03– 3.13	SL 6730S	4000	5	1.20	1.03	0.3	5	Al	–
2		R 32 WR 284 WG 10	3.03– 3.13		1500	5	1.20	1.03	0.4			
3		HN-type	1.0 – 1.1		10	0.1	1.30	1.04	0.7			

Finish: Chromate per MIL-C-5541A and dull black paint for aluminium
Silver and dull black paint for brass

Pressurization: 0.2 MPa diff (2 ATA)

Leakage: max 25 cc/min at 0.2 MPa diff (2 ATA)

Temperature range: –40°C to + 85°C operating
–70°C to +125°C storage

Life: 10–50 · 10^6 revolutions guaranteed (depending on model)

Multi-channel

Channel no.	Style		Frequency range GHz	Model	Power[1] peak kW	Power[1] avg kW	VSWR max	WOW max (VSWR)	Insertion loss dB max	Starting torque Nm	Material	Weight kg
1	U	**R32 WR 284 WG 10**	2.7 – 3.1	**SL 6745S**	1500	5	1.15	1.03	0.2	1	Al	8.2
2		**N-type**	2.7 – 3.1		10	10 W	1.30	1.05	0.5			
3		**N-type**	1.0 – 1.1		5	0.2	1.30	1.05	0.5			
1	U	**R 32 WR 284**	3.1 – 3.5	**SL 6745S/02**	500	5	1.2	1.03	0.3	1	Al	9
2		**N-type**	1.0–1.1 , 3.1 – 3.5		10/1	50 W	1.3	1.05	0.5			
3		**N-type**	3.1 – 3.5		10	10 W	1.3	1.05	0.5			
1	U	**R 32 WR 284 WG 10**	2.7 – 3.1	**SL 6800S**	1500	1.8	1.20	1.05	0.2	5	Al	25 appr
2		**N-type**	1.0 – 3.1		1	12 W	1.50	1.05	1.0			
3		**N-type**	2.7 – 3.1		5	0.1	1.30	1.08	1.0			
4		**N-type**	1.0 – 1.1		5	12 W	1.25	1.08	0.75			
5		**N-type**	1.0 – 1.1		5	12 W	1.25	1.08	0.75			
6		**N-type**	1.0 – 1.1		5	12 W	1.25	1.08	0.75			
1	L	**R 48 WR 187 WG 12**	5.4 – 5.9	**SL 6767G**	90	2	1.15	1.02	0.2	1.5	Al	4.5
2		**SMA/TNC**	1.0 – 1.1		0.5	10 W	1.3	1.08	0.5			
3		**SMA/TNC**	1.0 – 1.1		0.5	10 W	1.3	1.08	0.5			
1	U	**R 48 WR 187 WG 12**	5.4 – 5.9	**SL 6773G**	25	0.25	1.3	1.05	0.3	0.5	Al	3.5
2		**WG**	10.0 –10.25		25	0.2	1.5	1.06	0.5			
3		**N-type**	0.3 – 5.9		10	2 W	1.3	1.06	0.8			
1	U	**R84 WR 112 WG 15**	10.0 –10.25	**SL 6776H**	200	2	1.2	1.05	0.35	0.5	Al	4
2		**WG**	8.5 – 9.5		250	0.2	1.2	1.05	0.3			
3		**N-type**	0.6 – 8.8		1	0.04	1.5	1.05	1.0			
1	U	**R 100 WR 90 WG 16**	8.5 – 9.6	**SL 6777X**	150	0.5	1.2	1.03	0.3	1	Al	1.76
2		**TNC**	1.0 – 1.1		1.5	0.2	1.3	1.08	0.5			
3		**TNC**	1.0 – 1.1		1.5	0.2	1.3	1.08	0.5			
1	U	**R 100 WR 90 WG 16**	8.5 – 9.6	**SL 6760X/02**	150	0.5	1.20	1.05	0.3	0.5	Al	5.6
2		**Coax 4.1/9.5**	1.0 – 1.1		5	0.2	1.30	1.05	0.5			
3		**Coax 4.1/9.5**	1.0 – 1.1		5	0.2	1.30	1.05	0.5			

[1] The power capacity of rotary joints are given for +25°C
0.1 MPa 2 μs pulsewidth, 500 Hz repetition rate and matched load.
[2] With integral slip-ring package.

Swivel joints

Swivel joints (±60°)

This is a joint for applications where full rotation is not required. The swivel joint is compact, with a low mechanical torque, and high peak power capacity.

Waveguide size	Frequency range GHz	Model	Flanges mate[2]	Power[1] peak MW	Power[1] avg kW	VSWR max	Insertion loss dB max	Starting torque Nm max	Material	Weight kg	Dimensions in mm A	Dimensions in mm B
R32 WR284 WG10	2.7 – 3.5	**PM 7380S**	UAR 32 mod	2	5	1.15	0.15	10	Al	7.2	155	163
R84 WR112 WG15	7.05–10.0	**PM 7380H**	UBR 84	0.2	0.5	1.15	0.3	0.7	Al	1.0	70	76
R100 WR90 WG16	8.2 –12.4	**PM 7380X**	UBR 100	0.15	1	1.15	0.35	0.4	Al	0.38	52	60
R140 WR62 WG18	12.4 –18.0	**PM 7380P**	UBR 140	0.06	0.5	1.15	0.35	0.3	Al	0.25	35	50
WRD475 D24	4.75–11.0	**PM 7380DX**	39000/3-038	0.02	0.75	1.35	0.75	0.7	Al	1.1	76	81
WRD750 D24	7.5 –18.0	**PM 7380DP**	39000/3-072	0.01	0.5	1.35	0.75	0.4	Al	0.35	50	55

Finish: Chromate per MIL-C-5541A and paint for aluminium

Pressurization: 0.2 MPa diff (2 ATO)

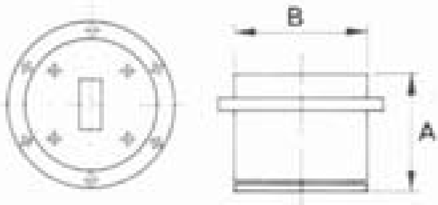
Leakage: max 25 cc/min at 0.2 MPa diff (2 ATO)

Temperature range: −40°C to +85°C operating
−70°C to +125°C storage

Life: min 15 · 10^6 cycles guarantees

[1] The power capacity of rotary joints is given for +25°C, 1 ATA 2 μs pulse width, 500 Hz repetition rate and matched load.

[2] Flange face conforms to: (plain flanges) for rectangular waveguide MIL-F-3922/53 or IEC154. Type B for double ridge waveguide USA MIL-39000/3.



Stackable and hollow shaft non contacting

Rotary joints suitable for stacking are available in two different choke coupled versions.

One exampe is the around-the-mast version, "pancake", with low height and large centre hole, 85 mm. It is available with type N/SMA or type N/N connectors. Another example is a "double pancake" with two channels.

The other type, SL 6805, is a more compact version with centre hole of only 10 mm. This enables you to stack 4–5 joints in a row. A typical bandwidth is 10 percent.

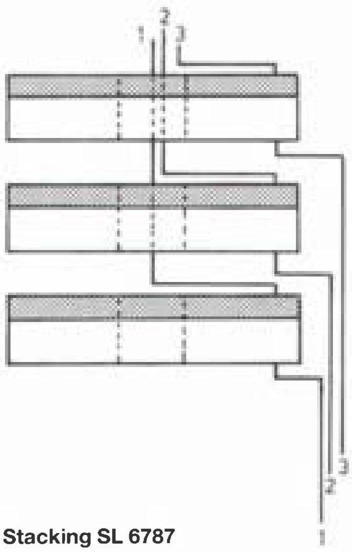
Technical data

Type of connectors	Frequency range GHz	Model	Power[1] peak kW	Power[1] avg W	VSWR max	WOW in VSWR	Insertion loss dB max	Starting torque Nm max	Material	Weight kg	Dimensions H	Dimensions D	Centre Ø
Single channel													
type N/SMA	1.01–1.10	**SL 6787**	10	10	1.3	1.10	0.5	1.0	Al	6	61	300	85
type N/N	1.0 –1.10	**SL 6802**	10	10	1.3	1.10	0.5	1.3	Al	6	61	300	85
type SMA	3±150 MHz	**SL 6805**	0.01	0.5	1.3	1.08	0.5	0.3	Brass	0.5	70	65	10
type SMA/SMA	3.0–3.6	**SL 21600**	1	1	1.3	1.05	0.5	0.3	Al	0.4	51	86	13
Dual channel													
type N	1.25–1.35	**SL 6795**	10	10	1.3	1.08	0.5	1.4	Al	6	101	300	51
type N	1.0 –1.1		10	10	1.3	1.08	0.5						

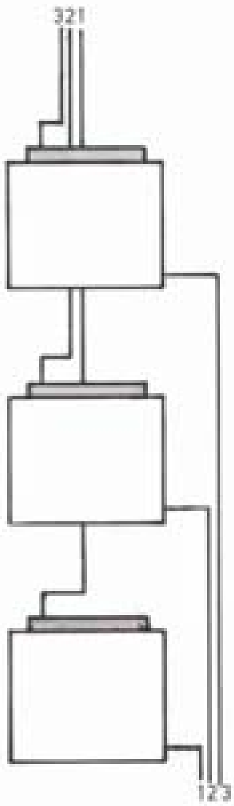
[1] The power capacity of rotary joints are given for +25°C 0.1 MPa (1 ATA) 2μs pulsewidth, 500 Hz repetition rate and matched load.

Temperature: operational −30°C to + 85°C
storage −40°C to +100°C

Life: Min 50 million revolutions with periodic lubrication.



Stacking SL 6787



Stacking SL 6805

Coaxial rotary joints

DC-40 GHz

The series of single-channel coaxial rotary joints consists of 5 models in different frequency ranges DC-40.0 GHz.They are intended for use in systems for medium power. The joints are weatherized to withstand severe environmental conditions.

Contact types

The sliding-contact types are designed with spring loaded precious metal contacts and are very compact. These types have the frequency range extended down to DC.

Choke-type

The PM 7893 choke joint has low torque and improved noise characteristics. It is recommended for high speed applications up to 2000 rpm.

Multichannel

Coaxial rotary joints are available up to 12 GHz, both contacting and non contacting types.

Single-channel

See also page 55 for coaxial stackable rotary joints.

Type of connectors	Frequency range GHz	Model	Power[1] peak kW	Power[1] avg kW	VSWR max	WOW in VSWR	Insertion loss dB max
type K female/female	DC-40	**PM 7889/11**	2 1	50 W at 1 GHz 25 W at 10 GHz	(DC-26 GHz) 1.75 31–36 GHz 2.5	1.0 (DC-26) 1.00 1.5 31–36 1.1	(DC-26GHz) 1.0 31–36 GHz 1.5
type N[2] male/female	DC-12.4	**PM 7890**	10	0.5 (DC-3 GHz) 0.2 (3–12 GHz)	1.30 (DC-8 GHz) 1.50 (8–12.4 GHz)	1.03	0.2 (DC-8 GHz) 0.3 (8–12.4 GHz)
type SMA female/female	DC-18.0	**PM 7892**	1.0	0.05	1.30 (DC-12 GHz) 1.50 (12–18 Ghz)	1.02	0.3 (DC-12 GHz) 0.6 (12–18 GHz)
type N male/female	2–10	**PM 7893**	5.0	0.1	1.40	1.03	0.3
type TNC female/female	DC-11	**PM 7895**	3.0	0.4 (DC-3 GHz) 0.2 (3–11 GHz)	1.30 (DC-8 GHz) 1.50 (8–11 GHz)	1.03	0.2 (DC-8 GHz) 0.3 (8–11 GHz)
type SMA female/female	8.5–9.6	**SL 6778**	3.0	0.05	1.5	1.05	0.3

[1] The power capacity of rotary joints are given for +25°C
0.1 MPa (1 ATA) 2 μs pulsewidth, 500 Hz repetition rate and matched load.

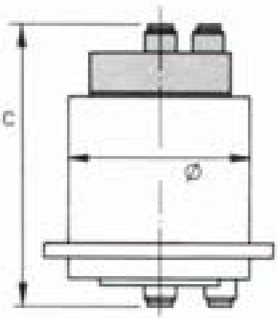
[2] PM 7890/01 female/female.

Multichannel coaxial rotary joints

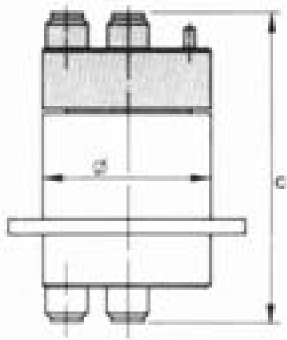
See also page 55 for coaxial stackable rotary joints.

Channel no	Style	Size	Frequency range GHz	Model	Power[1] cap peak kW	avg W	VSWR	WOW	Insertion loss dB	Starting torque Nm	Material	Weight kg	Dimensions in mm A	B	C	Ø
1	I	N-type	DC-12	**SL 6758**	15	50	1.50	1.05	0.5	0.2	Al	1.0	–	–	113	65
2		N-type	DC-3		15	50	1.70	1.08	0.5							
1	I	N-type	1.0–1.5	**SL 6770**	10	10	1.25	1.05	0.3	0.5	Al	–	–	–	136	90
2		N-type	1.0–1.15		10	10	1.30	1.08	0.4							
1	I	N-type	1.0–1.1	**SL 6781**	10	25	1.25	1.08	0.4	1.5	Al	8	–	–	380	108
2		N-type	1.0–1.1		10	25	1.25	1.08	0.6							
3		N-type	1.0–1.1		10	25	1.25	1.08	0.6							

[1] The power capacity of rotary joints are given for +25°C 0.1 MPa (1 ATA) 2 μs pulsewidth, 500 Hz repetition rate and matched load.

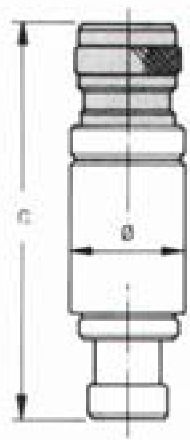


SL 6770

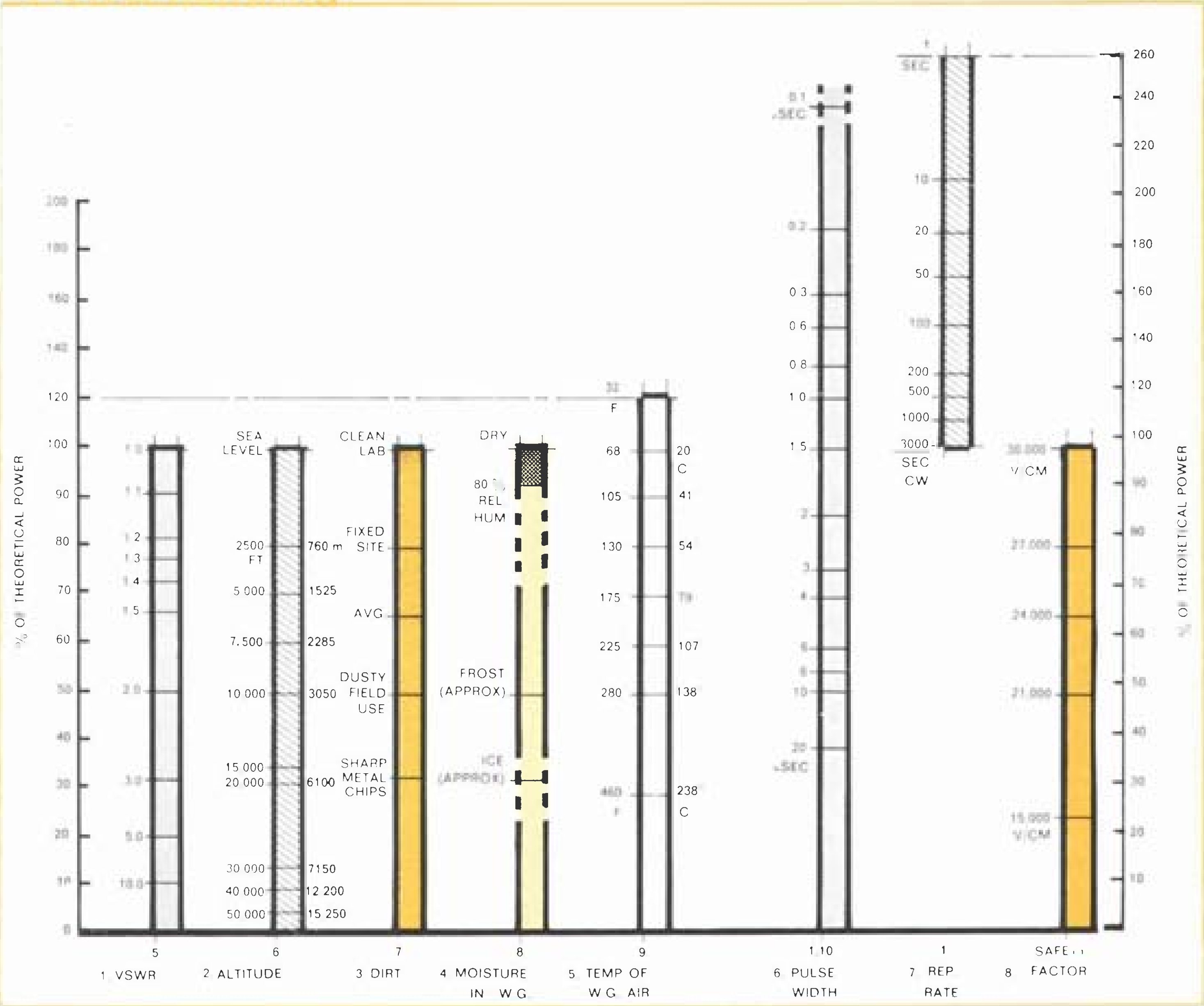


SL 6758

Starting torque Nm max	Rot speed rpm	Material	Weight g	Dimensions C	Ø
0.014	200	Stainless steel	60	51	15
0.05	500	Stainless steel	130	78.5	23
0.03	350	Stainless steel	40	55	15
0.02	2000	Stainless steel	140	82	23
0.05	500	Stainless steel	96	70.8	23
0.03	500	Brass/Gold	50	35	13



Power handling



1. System parameters affecting waveguide power handling capacity are derived by aligning each parameter horizontally with the vertical scales.

How to use the charts

Consider a ground-based radar set used from sea level to 10,000 feet which operates with a peak output power of 4 MW at 3.9 GHz. The duty cycle is 6 μsec at 300 pulses per second, and the VSWR at the transmitter output is 1.4 using WR 284 waveguide. System components most directly affecting the power capability include straight waveguide and bends, side wall couplers and a rotary joint with a type of door knob transition. The temperature at 10,000 feet, the extreme case, is approximated at 90° due to ambient plus 20° temperature rise due to signal attenuation in the waveguide, a total of 110°F.

From Figure 1 using a straight edge, the percentages of theoretical power realized due to each condition may be read off as follows:

VSWR of 1.4 resuls in 73%.
Altitude of 10,000 feet results in 50%.
Dirt (fixed site) results in 80%.
Temperature (110°F) results in 88%.
Pulse width (6 μsec) results in 60%.
Repetition rate (300) results in 125%.
Safety factor, E (using 30,000 V/cm) results in 100%.
(No safety factor will be considered in this first try).
Components result in 35%.
(The rotary joint is the critical one here).

The cumultative effect of all these parameters is found by multiplying all percentages; (0.73) (0.50) (0.80) (0.88) (0.60) (1.25) (1.00) (0.35) = 0.0675 or 6.75%.

The rapid calculation indicates that under practical operating conditions, the waveguide system can only handle 6.75% of the theoretical power of MW or 675,000 W peak. This figure does not even approach the desired peak power output of the radar of 4 MW, so steps muist be taken to increase the power handling capacity of the system.

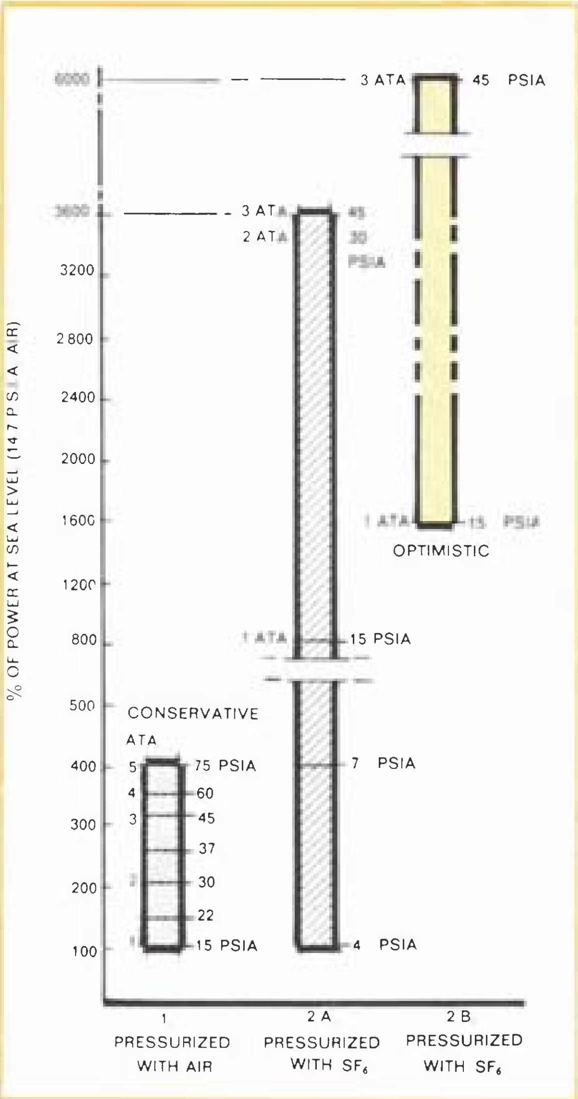


Fig 2. Ways to increase power handling capacity include pressurizing with air or SF, as well as special methods such as cooling, purging air through the guide, or creating special waveguide sizes.

Pressurization

Since Figure 1 is referenced to power handling capacity with 14.7 psia or 1 atmosphere (air) in the waveguide line and in the previous calculations it was assumed an altitude of 10,000 feet existed (resulting in 50% of theoretical power), the next step is to re-evaluate the power capacity at sea level. From Figure 1, 14.7 psia power equals 100% of the theoretical. Therefore, with 14.7 psia (air) in the waveguide, the power capacity is double that at 10,000 feet or 1.35 MW. To further increase the system power capacity, various means described in Figure 1 may be considered. The most commonly used method consists of pressurizing the system (waveguide and related components) with air since this is readily available and equipment for this purpose is available from numerous manufacturers at reasonable prices and delivery. Since the desired power to carry is 4 MW and the power handeled at 15 psia is 13.5 MW, the increase still required = 4.00/1.35 x 100 = 300%. On reading the pressurized with air scale at 300% it is seen that an air pressure of approximately 41 psia is required. By using 45 psia (35 psi gauge at 10,000 feet altitude) a safety factor will be introduced. Since pressurization is required, all components in the line must be designed to withstand this pressure.

MICROWAVES • June, 1972
J. Ciavolella, Senior Engineer

Double-ridge waveguide products

Rotary joints

WRD 475 D 24 Single channel	PM 7364DX 4.75–11.0 GHz page 48
WRD 475 D 24 Dual-channel	PM 7896DX 4.75–11.0 GHz page 50
WRD 750 D 24 Single channel	PM 7364DP 7.5 –17.5 GHz page 48
WRD 750 D 24 Single channel	PM 7897DP 7.5 –17.5 GHz page 48
WRD 750 D 24 Dual-channel plus SMA	PM 7896DP 7.5 –17.5 GHz page 50

Medium power loads

WRD 475 D 24 20 W average	PM 7220DX 4.75–11.0 GHz page 68
WRD 750 D 24 10 W average	PM 7220DP 7.5 –18.0 GHz page 68

High power loads

WRD 475 D 24 600 W average	PM 7223DX 4.75–11.0 Ghz page 68
WRD 475 D 24 400 W average	PM 7223DP 7.5 –18.0 GHz page 68

Transitions waveguide/coaxial

WRD 475 D 24/N	PM 7325DX 4.75–11.0 GHz page 69
WRD 475 D 24/TNC	PM 7326DX 4.75–11.0 GHz page 69
WRD 750 D 24/N	PM 7325DP 7.5 –18.0 GHz page 69
WRD 750 D 24/TNC	PM 7326DP 7.5 –16.0 GHz page 69

Double-ridge waveguide products

Waveguide switches

WRD 475 D 24	Transfer latching	PM 7286DX	4.75–11.0 GHz	page 35
DR 19	Transfer latching	SL 6643	4.75–11.0 GHz	page 35
WRD 650 D 28	Transfer latching	SL 6645	6.5 –18.0 GHz	page 35
WRD 750D 24	Transfer failsafe	PM 7288DP	7.5 –18.0 GHz	page 35
WRD 750 D 24	Transfer latching	PM 7289DP	7.5 –18.0 GHz	page 35
WRD 750 D 24	Transfer latching	PM 7304P	7.5 –18.0 GHz	page 35

Swivel joints

WRD 475 D 24	PM 7380DX	4.75–11.0 GHz	page 54
WRD 750 D 24	PM 7380DP	7.5 –18.0 GHz	page 54

Right-angle bends

WRD 475 D 24 E-plane	PM 7345DX	4.75–11.0 GHz	page 69
WRD 475 D 24 H-plane	PM 7350DX	4.75–11.0 GHz	page 69
WRD 750 D 24 E-plane	PM 7345DP	7.5 –18.0 GHz	page 69
WRD 750 D 24 H-plane	PM 7350DP	7.5 –18.0 GHz	page 69

Sweep oscillator

Sweep oscillator

The sweep oscillator PM 7022X is designed for swept frequency measurements at low cost with the highest accuracy. Only necessary functions have been included in order to keep the price low. The result is a compact, reliable instrument, easy to operate giving a min output power of 10mW over the whole frequency range. It has variable sweep speeds for use with both oscilloscopes and pen recorders.

Specifications PM 7022X

Frequency range

8.0–12.4 GHz

RF power

10 mW min, max 6 dB variation

Harmonics:	–30 dBc
Nonharmonics:	–50 dBc

Frequency accuracy (25°C)

CW-mode F_1:	±40 MHz
Sweep linearity:	±1% of sweep width

Frequency stability

–10°C to +45°C total:	100 MHz
10% mains voltage variation:	1 MHz
Residual FM (CW-mode):	15 kHz peak at 10 kHz BW
With load VSWR 3:1, all phases:	1 MHz

Power

Line voltages:	110–127–220–240 V ±10%, 50–60 Hz
Consumption:	50 VA

Dimensions and weight

Dimensions:	235x130x265 mm excl handles
Weight:	7 kg

CW automatic scan

Sweeps from F_1 to F_2 as set in 10 MHz increments with the two thumbwheel settings. These are calibrated and independent. The sweep can be either up or down in frequency.

CW manual scan

Single frequency output.

The frequency can be set anywhere between F_1 and F_2 by MANUAL SCAN knob.

Recurrent sweep. Continuously variable sweep speed from 20 ms to 200 ms.

Slow signal

Single sweep triggered by TRIG button. Continuously variable from 5 seconds to 50 seconds.

External sweep

When the CW-button is pressed (MANUAL SCAN set to F_1) the frequency can be swept externally with a sweep voltage applied to EXT SWEEP connector. Zero volt for F_1 and +10 volt for F_2. Input resistance 1 kohm.

Sweep out

Zero volt corresponds to F_1 and +10 volt corresponds to F_2. The output voltage is proportional to the instant output frequency (also operating in the CW-mode).

Display blanking

One positive and one negative output each giving a pulse of 5 volt coincident in time with sweep retrace.

Pen lift

NO: Contact normally open.
NC: Contact normally closed.

RF blanking

ON: The RF turns off automatically during sweep retrace and remains off until next sweep starts.

OFF: The RF is on also during retrace. The sweep and retrace times are equal.

Reference sweep out

Direct coupled voltage proportional to instantaneous frequency. Zero volt at 8.0 GHz and +5 volt at 12.4 GHz. Compatible with Hewlett Packard Network Analyzer HP 8410S, and frequency response test set HP 8755.

CW filter

To give low incidental FM (CW operation only).

Gunn-oscillator

Frequency meters Digital readout

Gunn oscillator

The oscillator PM 7015X is a cavity oscillator mechanically tunable over a broad frequency range in the X-band. The Gunn diode is post mounted in the high Q cavity and the bias voltage is applied to a BNC jack connector. The high precision tuning mechanism ensures a smooth tuning, free from irregularities and backlash. An engraved direct calibrated frequency scale enables frequency settings. The PM 7015X has a high frequency stability and is easy to tune. This makes it very suitable in measuring set-ups.

Specifications PM 7015X

Frequency range:	8.5–9.6 GHz
Output power min:	5 mW
Load VSWR max:	1.5
Temperature range:	0–60°C
Waveguide:	R 100 (WR 90, WG 16)
Flange:	Mates UBR 100
Gunn diode:	PM 7740 (CXY11C)
Gunn voltage negative:	7–10 V/150 mA surge 300 mA
Power supply:	PM 7815
Weight:	180 g
Length:	87 mm (max)
Material:	Brass, nickel-plated aluminium, black anodized tuning knob

PM 7070X/bg

Frequency meters

These frequency meters offer the unique feature of digital readout of the frequency. They are available in coaxial configurations from 2.5 to 4 GHz and in waveguide from 8.2 to 12.4 GHz.

The cavity

The cavity is cylindrical with a movable plunger. Two resonant modes are used. The cylindrical TM_{010}-mode and the coaxial TEM-mode.

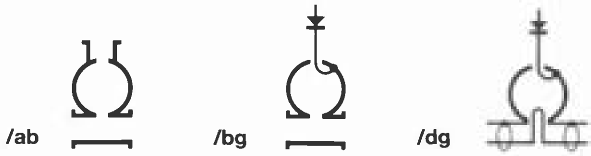
The result is an almost perfectly linear relationship between the resonant frequency and the lenght of the plunger.

The digital readout

A linear gearbox couples the plunger to a dial and a mechanical counter on which the last digit is in MHz. On some models every 100 kHz is also indicated.

Coupling configurations

The cavity has two coupling windows, to which coaxial or waveguide sections are connected.



Accuracy

Every cavity is calibrated to give a direct reading accuracy of ±0.1%, over a band width of 1.5:1 regardless of the type of coupling elements used. An individual calibration curve is supplied with every frequency meter. The use of this curve gives an accuracy of ±0.02%.

Loaded Q

The loaded Q is such as to provide a suitably wide and deep indication either when the frequency meter is used in transmission or reflection circuits. It is in the order of 1000–3000.

Standard models

2.5– 4.0 GHz PM 7070S/dg
8.2–12.4 GHz PM 7070X/ab, PM 7070X/bg,
PM 7070X/dg

Option

The above standard models are stock items. Frequency meters for other frequency bands are available on quantity order.

Rotary vane attenuator

The PM 7101-series presents a wide and accurately calibrated attenuation range. Two models cover standard waveguides between 8.2 and 18 GHz. As they utilize the rotary vane principle the attenuation is independent of temperature and humidity and assures negligible phase shift variations over the attenuation range.

Short length

The instruments are made very short as to take a minimum of spaces in a microwave measuring bench. It makes them also ideal for use in systems. In this respect the square shape will allow for easy mounting.

60 dB attenuation range

Despite the short length a large attenuation range and perfect matching was obtained because of close machining tolerances and precision casting of the mode transformers.

High accuracy

The readout scale is a 60 cm long mylar tape. A spring loaded driving mechanism assures a good accuracy and resettability.

Material and finish

Waveguide and cabinett are made of aluminium. Waveguide inside chromated, cabinet outside grey enamel.

Waveguide range GHz	Frequency	Model	Flange mates	Power average W	Weight kg	Length mm
R 100 WR 90 WG 16	8.2–12.4	**PM 7101X**	UBR 100	10	1.35	281
R 140 WR 62 WG 18	12.4–18.0	**PM 7101P**	UBR 140	5	0.93	198

Attenuation range: 0–60 dB

Accuracy:
0–10 dB: 0.1 dB
10–40 dB: 1% of reading
40–50 dB: 2% of reading
50–60 dB: 3% of reading
(up to 0.85 x highest frequency)

Insertion loss: 0.75 dB

VSWR: 1.15

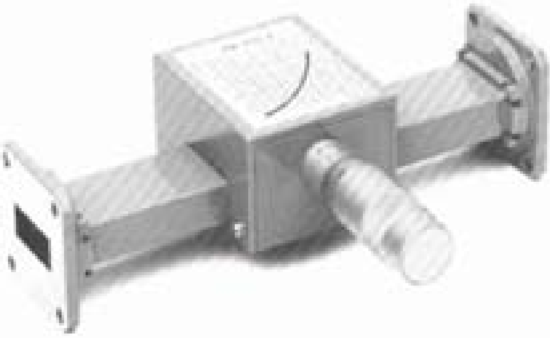
PM 7101X

Variable attenuator

The attenuation is achieved by moving a resistive vane, in the waveguide. The E-field increases towards the centre and thus the attenuation increases when the vane is moved towards this position.
The attenuation as a function of the micrometer reading is given on the calibration chart attached to the instrument.

Specifications

Model	**PM 7110X**
Frequency range:	8.2–12.4 GHz
Attenuation:	0–35 dB
Accuracy:	<10%
Insertion loss:	0.2 dB
VSWR:	1.10
Power avg	1 W
Waveguide:	R 100 (WR 90, WG 16)
Flange mates:	UBR 100
Material:	nickel plated brass, grey enamel
Weight:	600 g
Length:	164 mm

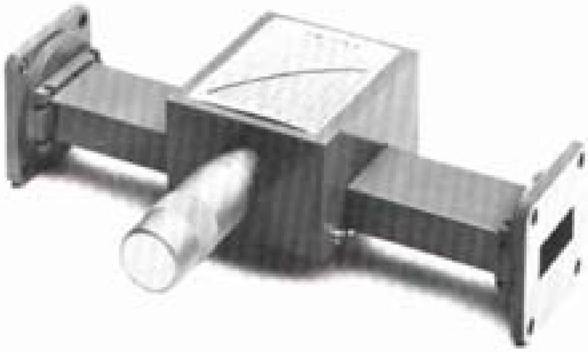


Calibrated phase shifter

The phase shifter PM 7175X is a semi-precision instrument. The phase shift is obtained by moving a specially shaped teflon vane parallel to the E-field direction, the position being controlled by a micrometer mechanism. The relation between phase shift and micrometer reading is given in a calibration graph attached to the instrument.

Specifications

Model	**PM 7175X**
Frequency range:	8.2–12.4 GHz
Phase shift:	0–200°
Accuracy:	±5° at calibration points ±15% of setting over frequency band
Insertion loss:	0.5 dB
Variation of losses with phase setting:	0.4 dB
VSWR:	1.2
Power avg	2 W
Waveguide:	R 100 (WR 90, WG 16)
Flange mates:	UBR 100
Material:	Nickel plated brass waveguide grey painted
Weight:	600 g
Length:	164 mm



Detectors

Wideband coaxial detectors

These detectors are designed for wide band systems applications.

Field replaceable diodes

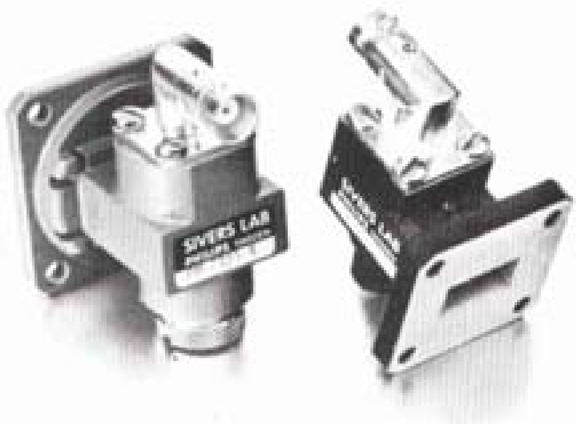
The detectors have a low video impedance and are suitable for the detection of fast pulses. The diodes are field replaceable and of standard types. Built-in DC-return for optimum sensitivity/matching is provided.

Meet MIL-standards

They are designed to meet severe MIL-environmental standards. They have a light weight construction using standard 3 mm miniature connectors at both ends.

Low level detectors PM 7195X and PM 7195P

These waveguide detectors are designed for low level detection. The diode is mounted in the centre of the waveguide in front of a fixed short circuit. An inductive section between the flange and the diode flatten the response and reduce the VSWR. The rugged designs meet military requirements and the material are chromated aluminium, painted grey enamel (PM 7195X) or dull black paint (PM 7195P).



Measuring detectors

The PM 7520 and PM 7197X measuring detectors are used in broadband swept frequency measurements, where low reflections and a flat frequency response are required. But they also find applications in all microwave systems, where low reflections and high accuracy are required. The point-contact diodes have a miniature encapsulation and are field-replaceable. The video output polarity can be reversed.

Matched pairs

For applications where tracking is required matched pairs are available.

Finish

The coaxial detector PM 7520 is made of stainless steel with SMA-male input connector and a BNC-female output connector.

The waveguide detectors are made of aluminium (chromated) and grey painted. They have a BNCfemale output.

Specifications

	Wideband models		Measuring models		Low level models	
Model:	**PM 7512***	**PM 7513***	**PM 7520**	**PM 7197X**	**PM 7195X**	**PM 7195P**
Diode type: (ordering no)	point contact (PM 7724)	Schottky (PM 7732)	point contact (PM 7725)	point contact (PM 7725)	point contact (PM 7721)	point contact (PM 7726)
Frequency range:	2–18 GHz	2–18 GHz	10 MHz–18 GHz	8.2–12.4 GHz	8–11 Ghz	12.4–18 Ghz
TSS (video BW 1 MHz) typ.:	–50 dBm	–50 dBm	–40 dBm	–40 dBm	–50 dBM	–50 dBm
Bias:	20 μA	100 μA	0	0	0	0
VSWR typ.:	7	7	1.8 max	1.5 max	5	5
Freq response 2–12 GHz:	±2 dB	±2 dB	±0.5 dB	±0.3 dB	–	–
12–18 GHz:	±3 dB	±4.5 dB	±1.0 dB	±0.3 dB	–	–
Typical output voltage into 1 kohm at 10 GHz:	2 mV/μW	1.5 m V/μW	0.4 mV/μW	0.4 mV/μW	–	–
Level of 1 dB deviation from square law; typical	–17 dBm	–16 dBm	–12 dBm	–12 dBm	–	–
Saturation power level:	+20 dBm	>+20 dBm	+20 dBm	+20 dBm	+20 dBm	+20 dBm
Max RF power CW:	+20 dBm	+20 dBm	+20 dBm	+20 dBm	+20 dBm	+20 dBm
Output impedance:	1.5 KΩ//12 pF	1.5 KΩ//12 pF	–	–	–	–
Connectors input:	SMA-male	SMA-male	SMA-male	UBR 100	UBR 100	UBR 140
output:	SMA-male	SMA-male	BNC-female	BNC-female	BNC-female	BNC-female
Material:	gold plated brass		stainless	Al	Al	Al
Temperature:	–55°C to +110°C		–	–	–	–
Humidity:	95%, +25°C to +55°C		–	–	–	–
Weight:	18 g	18 g	20 g	100 g	85 g	85 g
Output polarity	neg	neg	neg	neg	pos	pos

* Vibration: sine 10– 55 Hz, amplitude 0.7 mm
sine 55–2000 Hz, amplitude 10 g

Bump test: 40 g (1000 bumps)

Waveguide loads

Low reflection, PM 7220-series

The PM 7220-series terminations have a very low VSWR, specified less than 1.05 over the full waveguide range. They are constructed with a long dissipative dielectric taper securely fastened to the waveguide.

Low power miniaturized, PM 7222-series

These loads have a total length not much more than the thickness of a standard waveguide flange. The patented absorber gives the load a total VSWR of less than 1.10 over the full waveguide frequency range. Power absorption is 0.5–1 W depending on frequency.

Medium power, PM 7224-series

This series of loads are intended for average power levels of 15–20 W, in applications where the available space is restricted. Max ambient temperature is +50°C.

High power, PM 7223-series

The PM 7223-series loads are high power loads for high-power transmitters. They can dissipate high power without any degradation in reflection coefficient.

The loads employ transverse cooling fins and the actual dissipation of power takes place in a thin layer on the walls within the waveguide. The length of the waveguide where most of the power is dissipated is essentially empty and does not contain any object which might reduce the peak power capacity. This capacity is equal to that of the empty guide itself and can be increased by pressuration.

The average power handling capacity of the termination is restricted by the requirements that the temperature of the dissipation material should not exceed 300°C. Because of the excellent thermal conduction between the dissipative material and the waveguide wall, forced air will greatly increase the power handling capacity of the terminations.

Specifications

Waveguide size	Frequency range GHz	Flange mates	Model	Power peak kW	Power avg W*	VSWR	Weight gram	Length mm
R 32 WR 284 WG 10	2.6 – 3.95	UAR 32	PM 7222S	2	2	1.10	100	33
			PM 7223S	3500	3000	1.05	6200	400
R 48 WR 187 WG 12	3.95– 5.85	UAR 48	PM 7222G	1	1	1.10	100	22
			PM 7223G	1600	1000	1.05	1200	300
R 70 WR 137 WG 14	5.85– 8.2	UAR 70	PM 7222J	0.7	0.7	1.10	80	17
R 84 WR 112 WG 15	7.05–10.0	UBR 84	PM 7223H	600	350	1.05	400	160
R 100 WR 90 WG 16	8.2 –12.4	UBR 100	PM 7220X	80	2	1.02	250	160
			PM 7222X	0.5	0.5	1.10	40	11
			PM 7224X	80	10	1.10	150	30
			PM 7223X	350	250	1.05	150	140
R 120 WR 75 WG 17	10.0 –15.0	MIL-F-3922/70-005	PM 7222M	0.5	0.5	1.15	35	11
R 140 WR 62 WG 18	12.4 –18.0	UBR 140	PM 7222P	0.5	0.5	1.10	30	8
			PM 7224P	40	5	1.10	25	20
			PM 7223P	200	150	1.05	130	90
WRD 475 D 24	4.75–11.0		PM 7220DX	–	10	1.05	130	200
			PM 7223DX	–	600	1.05	560	240
WRD 750 D 24	7.5 –18.0		PM 7220DP	–	10	1.05	70	150
			PM 7223DP	10	400	1.07	420	200

* at +25°C for PM 7223-series, derate linearly to 0 W at 300°C.

Transitions (adapters) WG to coaxial

All the transitions are designed for optimum performance over the entire waveguide operating frequency range. The dimensions are kept minimum without sacrificing mechanical or electrical performance.

Option

The listed transitions are stock items. Transitions for other frequency ranges and with other connectors are available on quantity order.

Waveguide size	Frequency range GHz	Model	Coaxial conn jack	Flange mates	VSWR max	Insertion loss dB max	Material[2]	Weight gram	Dimensions in mm L_1	L_2	H
Rectangular waveguide											
R 48 WR 187 WG 12	3.95– 5.85	**PM 7328G**	SMA	UAR 48	1.25	0.1	Al	200	21	40	32
R 84 WR 112 WG 15	7.05–10.0	**PM 7325H**	N	UBR 84	1.25	0.2	Brass	200	29	40	35
R 100 WR 90 WG 16	8.2 –12.4	**PM 7325X**	N	UBR 100	1.25	0.2	Al	100	22	40	34
R 100 WR 90 WG 16	8.2 –12.4	**PM 7328X**[1]	SMA	UBR 100	1.25	0.2	Al	40	10	19	19
R 120 WR 75 WG 17	10.0 –15.0	**PM 7328M**	SMA	UBR 120	1.25	0.2	Al	40	11	19	17
R 140 WR 62 WG 18	12.4 –18.0	**PM 7328P**	SMA	UBR 140	1.25	0.2	Al	30	9	16	15
Double ridge waveguide											
WRD 475 D 24	4.75–11.0	**PM 7325DX**	N	M-39000/3-036	1.25	0.25	Al	80	28	40	28
	4.75–11.0	**PM 7326DX**	TNC	M-3900/3-036	1.25	0.25	Al	80	28	40	28
WRD 750 D 24	7.5 –18.0	**PM 7325DP**	N	M-39000/3-072	1.5	0.5	Al	50	20	30	24
	7.5 –16.0	**PM 7326DP**	TNC	M-39000/3-072	1.5	0.5	Al	50	20	30	23

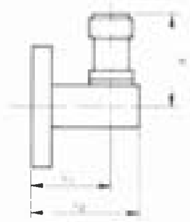
Temperature range: –40°C to +85°C operational

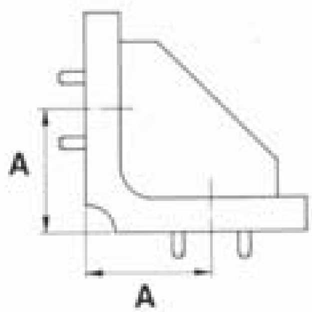
Finish (aluminium): grey enamel or dull black paint, flange face irridited

(brass): grey enamel or dull black paint, flange face nickel-plated

[1] A military version, with hermetically sealed transition and with a max leakage of 10^{-7} cc/sec is avaiable on request (limited freq range).

[2] Connector body stainless steel or gold-plated brass. See also "tailor made products".





Right angle waveguide bends

Waveguide size	Style	Frequency range GHz	Model	Flange mates	VSWR	Weight gram	Dimensions mm A
Rectangular waveguide							
R 100 WR 90 WG 16	E-plane	8.2 –12.4	**PM 7345X/01**	UBR 100	1.05	70	30
R 100 WR 90 WG 16	H-plane	8.2 –12.4	**PM 7350X/01**	UBR 100	1.05	60	30
Double ridge waveguide, miniature							
WRD 475 D 24	E-plane	4.75–11.0	**PM 7345DX**	M-39000/3-036	1.05	–	31.75
WRD 475 D 24	H-plane	4.75–11.0	**PM 7350DX**	M-39000/3-036	1.05	–	31.75
WRD 750 D 24	E-plane	7.50–18.0	**PM 7345DP**	M-39000/3-072	1.05	55	23.50
WRD 750 D 24	H-plane	7.50–18.0	**PM 7350DP**	M-39000/3-072	1.05	55	23.60

Tailor made products

Waveguide switch WR 650, R 14
Manually or motor-driven

Type No	Circuit	Operation	Peak power MW	dB min	Switching time max seconds	Weight kg
PM 7295L		manual	6	90	–	100
PM 7296L		latching	6	90	4	108

Frequency:	1.12–1.7 GHz
VSWR:	<1.05
Insertion loss:	<0.1 dB
Flange:	mates PDR14 (UG417/U)
Thread:	M8 (screws suppl)

Standard motor for PM 7296L:
collectorfree AC motor; 220 V–90 VA

Receiver protector PM 7125X

This brodband solenoid operated attenuator for waveguide R100 (WR90) has an attenuation of over 30 dB when closed and a loss less than 0.1 dB when opened. VSWR <1.05.

Hermetically sealed transition PM 7328X/05

For applications where it is of greatest importance that the system is air-tight there is a special hermetically sealed transition wg/coaxial with a maximum leakage of 10^{-7} cc/sec (limited frequency range).

Blast-proof sections SL 6638X, SL 6639P, SL 15693

Pressure sections are intended to protect underground radarstations, submarines etc, against heavy explosions.

Microwave education and training

A series of experimental booklets is available in up to five languages: English, French, German, Spanish and Swedish. A detailed description of how to perform the various experiments is given in such a way that even the unexperienced student will understand it without difficulty ("step by step-procedure"). The theoretical background is treated briefly almost without any mathematics. References to more theoretical books are given.

All components in the experiments are for X band use. For more detailed information we refer to the catalog "Education in applied microwaves".

Equipment

The instruments and components required for the experiments have been grouped as follows:

Basic Experiments I	Bench PM 7000X/02
Basic Experiments II	Bench PM 7001X
Basic Experiments III	Bench PM 7002X
Basic Experiments IV	Bench PM 7003X
Basic Experiments V	Bench PM 7004X

All the benches are composed of standard items widely used in research, development and by the service engineers all over the world. This means that the students will be trained on modern equipment and get a good feeling for microwaves in practice.

Editions available

Edition	English	German	French	Spanish	Swedish
Basic Experiments I	X	X	X	X	X
Basic Experiments II	X	X	X	X	X
Basic Experiments III	X	X	X		
Basic Experimets IV	X	X	X		
Basic Experiments V	X	X	X		

In this reference table you will find all microwave components for a certain microwave bench.

Type no	Description	Bench PM 7000X/02	PM 7001X	PM 7002X	PM 7003X	PM 7004X
PM 7015X	Gunn oscillator	1	1	1	1	1
PM 7017X	Varactor tuned oscillator	–	–	–	1	–
PM 7022X	Sweep oscillator	–	–	1	1	–
PM 7026X/01	Modulator	1	1	1	1	1
PM 7045X	Ferrite isolator	1	1	1	1	1
PM 7050X	Ferrite circulator	–	–	1	1	–
PM 7070X	Frequency meter	1	1	1	1	1
PM 7075X	Frequency meter, passing w g	1	1	1	1	1
PM 7076X	Frequency meter, endconn w g	–	–	–	1	–
PM 7083X	Frequency meter, diode mount	1	1	1	1	1
PM 7101X	Rotary vane attenuator	–	1	1	1	1
PM 7110X	Variable attenuator	1	1	1	1	–
PM 7142X	Standing wave detector	1	–	–	–	–
PM 7151X	Slide screw tuner	1	1	1	–	–
PM 7195X	Detector	1	1	1	–	1
PM 7197X	Detector matched	–	–	–	1	–
PM 7201X	Thermistor mount	–	1	–	1	–
PM 7216X	Movable short	1	1	1	1	1
PM 7220X	Termination	1	1	1	2	–
PM 7241X	Directional coupler, 10 dB	–	1	1	1	–
PM 7260X	Hybrid-T	–	–	–	1	–
PM 7317X	Antenna kit	–	–	–	–	1
PM 7320X/01	Horn antenna	2	–	1	2	2
PM 7325X	Transition w g/coax (type-N)	–	–	1	1	2
PM 7328X	Transition w g/coax (SMA)	–	–	2	–	–
PM 7345X	Waveguide bend E-plane	2	–	–	–	3

Type no	Description	Bench PM 7000X/02	PM 7001X	PM 7002X	PM 7003X	PM 7004X
PM 7350X	Waveguide bend H-plane	–	–	–	–	1
PM 7366X	Straight waveguide section	1	–	–	–	1
PM 7440/01	YIG-unit	–	–	1	–	–
PM 7580	Adapter, type N-male x2	–	–	–	–	2
PM 7700	Waveguide carrier	2	2	3	2	2
PM 7701X	Waveguide clamp	2	2	2	1	–
PM 7702X	Waveguide clamp	–	1	1	2	2
PM 7815	Gunn oscillator power supply	1	1	1	1	1
PM 7833	SWR-meter	1	1	1	1	1
PM 7842	Power-meter	–	1	–	1	–
PM 7888X	Rotary joint	1	–	–	–	1
PM 9051	Adapter, BNC-banana	–	2	–	–	–
PM 9067	BNC T-piece	–	1	1	2	–
PM 9585	Cable termination, BNC	–	–	–	1	–
PM 9710	Function generator	–	–	–	1	–
SL 19700	Parabolic antenna	–	–	–	–	1
SL 19701	Slot antenna	–	–	–	–	1
SL 19702/1	Helix antenna, right-hand wound	–	–	–	–	2
SL 19702/2	Helix antenna, left-hand wound	–	–	–	–	1
SL 19703	Microstrip antenna	–	–	–	–	1
SL 19704	Metal plane	–	–	–	–	1
SL 19705	Antenna stand	–	–	–	–	1
SL 80253	Coaxial cable, SMA-connected	–	–	2	–	–
SL 80254	Coaxial cable, BNC-connected	2	4	4	4	4
SL 80255	Coaxial cable, type N-connected	–	–	1	1	–
SL 80300	Oak bench	1	1	1	1	1
SL 80364	Laboratory stand	1	–	–	–	–
SL 80599	Measuring tape	–	–	–	–	1

Basic Experiments I

Basic Experiments I

This booklet is intended to be the primary in the microwave education series. It will make the student familiar with some basic concepts and components frequently used in microwave engineering.

The waveguide field

The booklet starts with an introduction describing microwaves propagating in a hollow rectangular waveguide. The electromagnetic fields and the fundamental model are also treated in brief.

Gunn oscillator

This part gives the start up instructions for Gunn oscillator. Futher experiments with Gunn oscillator in Basic Experiments II.

Frequency, wavelength and attenuation measurements

How is the wavelength in the rectangular guide related to that in the free space? How to measure the microwave frequency? What is attenuation and how is it expressed in decibel (dB)? All this is explained in the second experiment and put in practice through measurements.

SWR measurements

When reflections are present in a waveguide, an interference pattern or standing waves appear. The third experiment explains this and defines the standing wave (VSWR). Different ways to measure it are described e.g. the 3 dB method and the calibrated attenuator method. Both methods are investigated experimentally.

Impedance measurements The Smith chart

This experiment explains the characteristic impedance of a transmission line and how to graphically represent the impedance locus of the load connected to this line. It also describes the well-known Smith chart and uses some simple examples to explain its versatility. Measurements obtained by using a standing-wave detector enables the student to determine the actual load impedance value.

Antenna measurements

The basic antenna characteristics i.e. aperture, lobes, gain and beamwidth are explained. The antenna diagram of a horn antenna is measured as well as the antenna gain.

Basic Experiments II

This booklet brings the student in contact with some important measurement methods and also with a microwave source, the coupler and the detector.

Study of a Gunn oscillator

The first experiment deals with the Gunn oscillator, a source used in numerous applications ranging from advanced stable local oscillators to inexpensive sources for intruder alarms.

The experiment begins with the Gunn diode physics and the principle of operation. In the following measurements the voltage-current diagram is plotted and the oscillator power output versus frequency is recorded. For amplitude modulation of the microwave signal an external diode modulator is used. The modulation depth is measured in this experiment.

Power measurements

The objective of this experiment is to measure microwave power and to make clear how the bolometer (thermistor) bridge operates. Basic concepts like peak and average power, duty cycle and power level in dBm are explained. The low frequency bias power is measured with an oscilloscope. The measurement of the power level of a squarewave modulated signal serve as a practical exercise. The power meter is also checked against a precision attenuator.

The directional coupler and reflectometer measurements

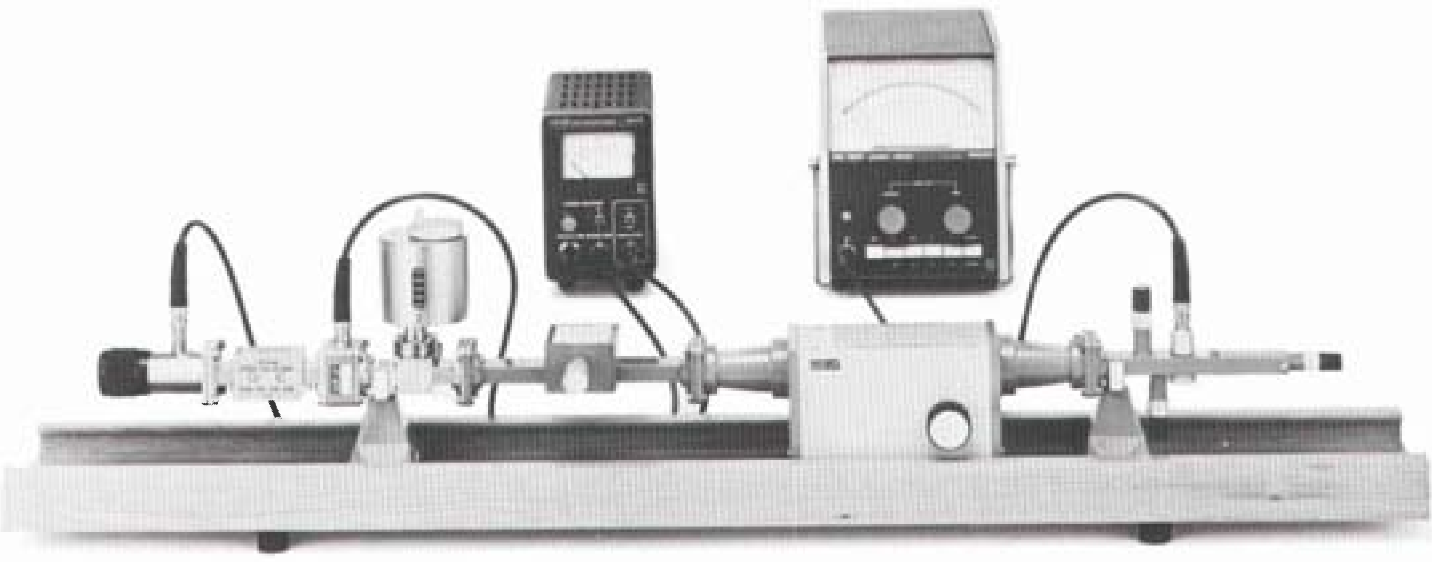
The coupling and directivity of a directional coupler are measured as well as the return loss from a test load. The accuracy of this measurement caused by the directivity of the coupler is considered.

Impedance match with the slide screw tuner

The slide screw tuner can be utilized to cancel the reflection from a mismatched load. In this experiment the Smith chart is used to graphically find location and value of the shunt admittance necessary to obtain matching conditions. The shunt admittance is realized using the slide screw tuner.

Microwave detectors

The point-contact, the Schottky barrier and the back diode detector are compared. The principle of detecting microwaves is explained and visualized in diagrams. The squarelaw behaviour of the detector is experimentally being tested. Some characteristics like voltage and current sensitivity are measured. A method of measuring TSS (tangiental sensitivity) is described.



Set-up for study of the Gunn oscillator

Basic Experiments III

Basic Experimnts III

This booklet treats some special components, as well as a versatile measurement method and an interesting principle. Still the scope of it falls within a basic microwave course.

Swept-frequency measurements

Swept-frequency measurements are certainly the method by far most used in testing microwave components. This experiment gives the basic around and how to use it on measuring insertion loss and return loss of both passive and active devices.

Nonreciprocal ferrite devices

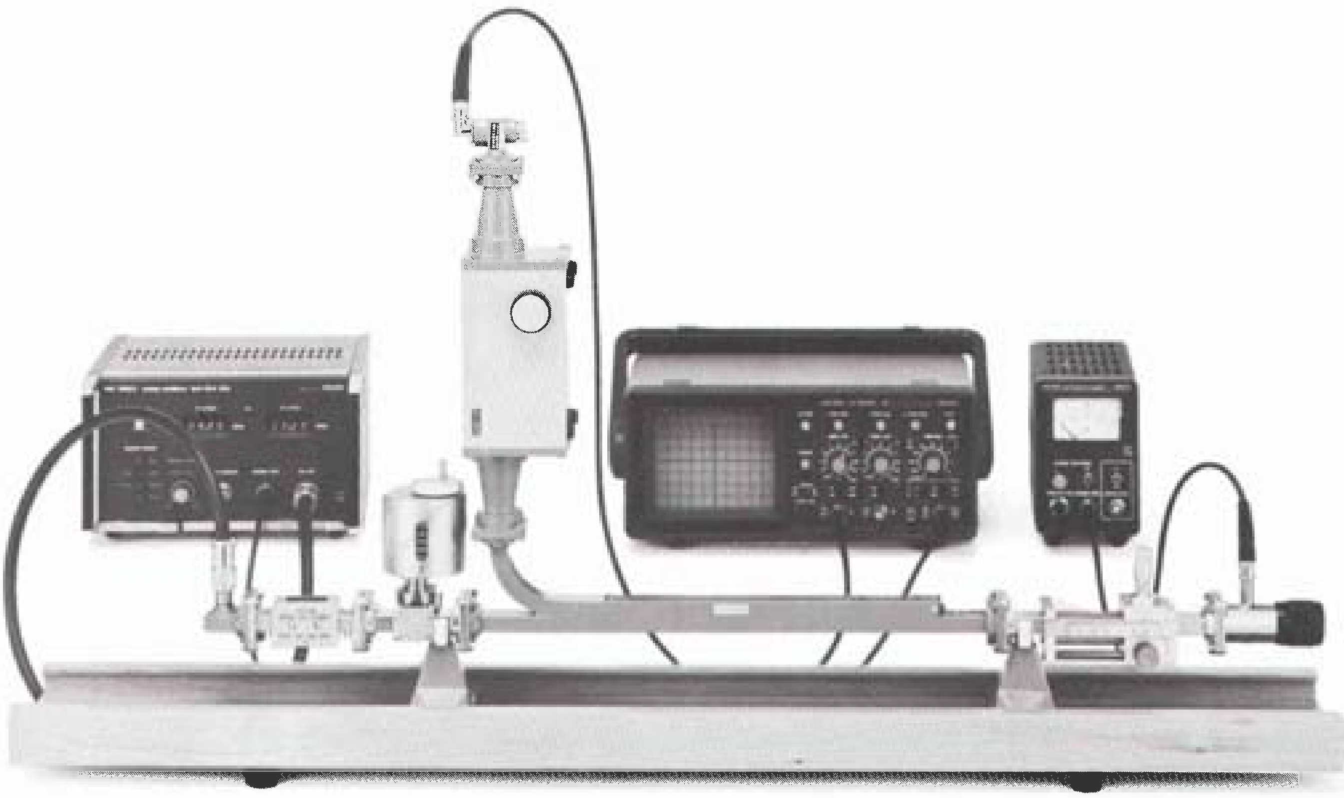
This experiment starts with a brief survey of the ferrite characteristics. The isolator and the circulator aare discussed. The isolation and insertion loss are measured on these devices.

The YIG-filter

Here the objective is to introduce the YIG-tuning. After a description of the ferromagnetic resonance, the YIG-filter and its passband characteristics e.g. off-resonance spurious, 3 dB bandwidth and selectivity are studied through practical measurements.

A study of the Doppler effect

This experiment treats the frequency shift (Doppler effect) caused by the motion of a frequency source relative the receiver. Various examples are discussed and the expression for the Doppler frequency is deduced. Some numerical examples illustrate this and the principle of a doppler radar is presented. Some measurements of the Doppler frequency using an X-band radar are presented.



Sweept frequency measurements

Basic Experiments IV

This is the fourth booklet in the series and it brings the student in contact with some new components and measurement methods. It is more directed towards component applications, than the preceding booklets.

Study of a waveguide hybrid-T

All the characteristics of a waveguide hybrid-T are measured.After an explanation of the function, using a basic approach, the decoupling and the insertion loss are measured. The mismatch of different arms (ports) are measured with remaining arms terminated. All the measurement results are compiled and compared with the theoretical values.

Frequency conversion

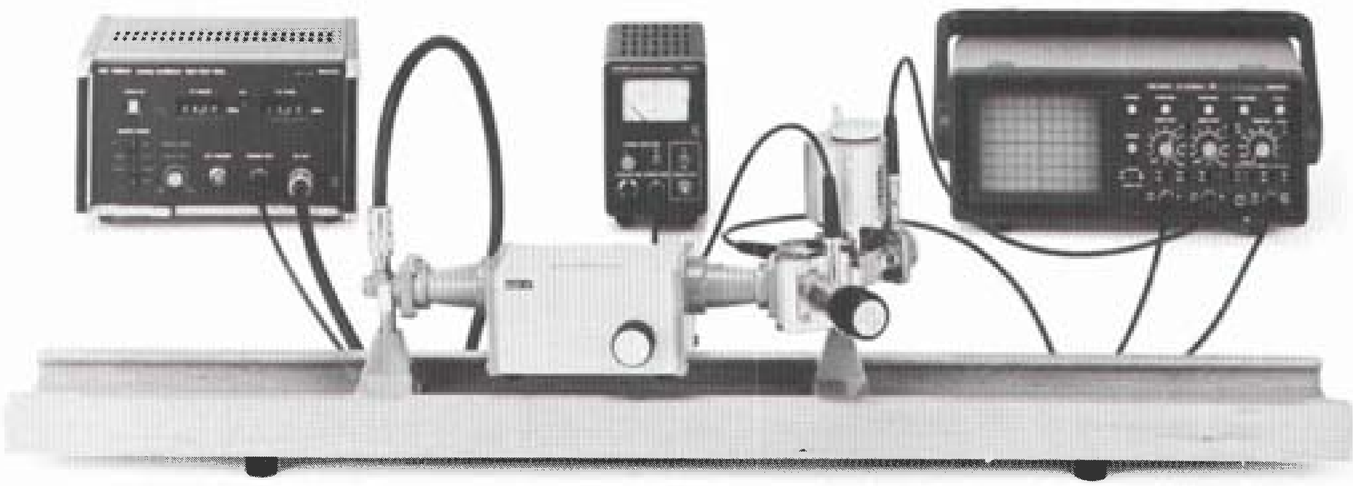
The objective of this experiment is to demonstrate the heterodyne frequency conversion (mixing) in a diode detector, and to measure its performance. After a presentation of some general definitions and practical aspects, the intermediate frequency output and the conversion loss of the mixer are measured.

A simple frequency-modulated microwave link

This experiment covers microwave frequency modulation and demodulation. A varactor tuned oscillator is modulated and the signal is transmitted from a transmitter horn to a receiver horn and a following frequency discrimination. The signal received is compared with the modulation signal applied to the varactor tuned oscillator.

Injection phase locking of a microwave oscillator

An interesting method of stabilizing the frequency of a microwave oscillator is the subject of this experiment. It brings up oscillator features such as locking bandwidth and loaded Q-value. These are measured on an injection locked Gunn oscillator, and the effect of the injected power level is studied.



Demonstration of injection phase locking.

Basic Experiments V

Basic Experiments V

The fifth booklet in our series of Basic Expriments is totally focused on antennas. Typical microwave antennas are described and the basic radiation features are measured.

Horn antenna

The basic antenna characteristics, i.e. aperture, lobes, gain and beamwidth, are explained. A standard gain for two different frequencies is determined with the help of two identical horn antennas and the E-plane antenna diagram of the horn is plotted.

Parabolic antenna, Slot antenna

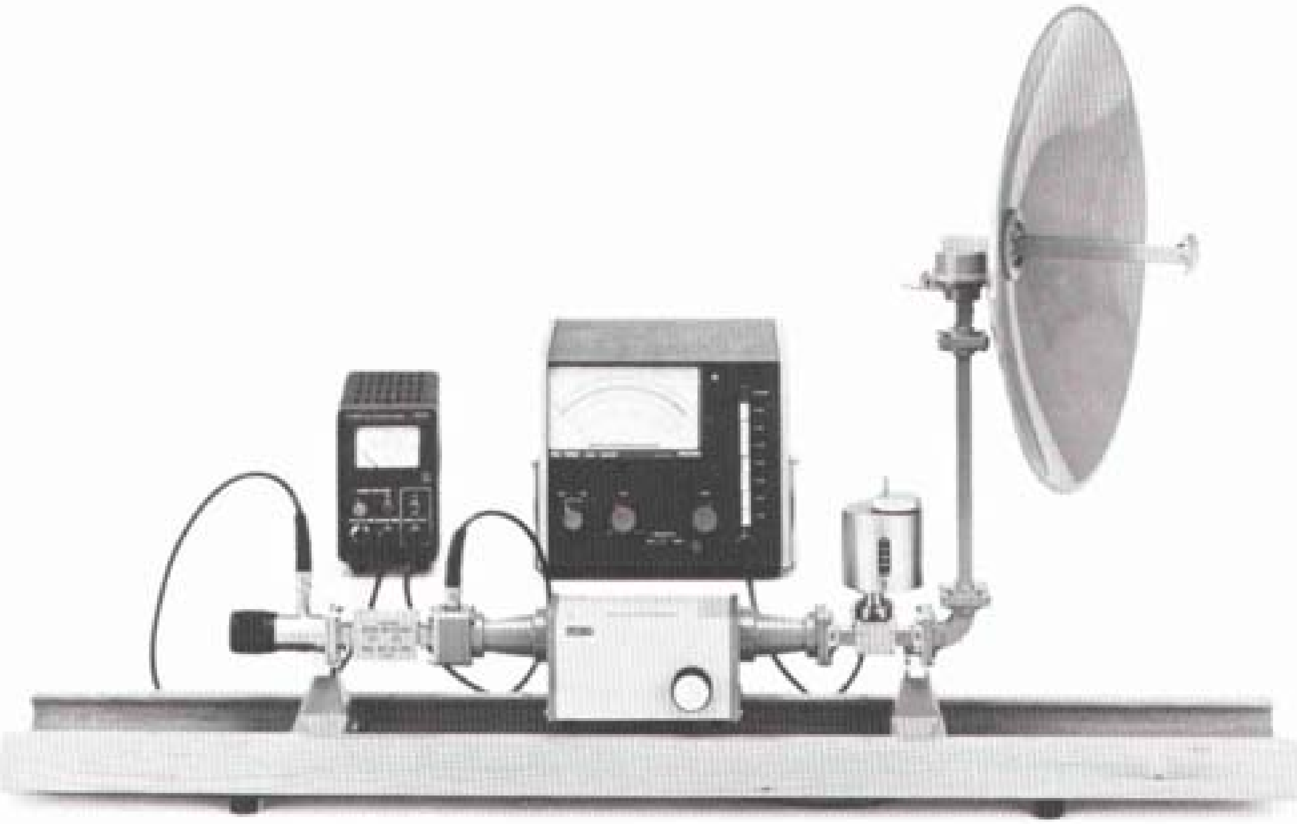
In the previous experiment the gain of an antenna was determined with the help of two identical antennas. In this experiment it is shown how to measure the gain if not two identical but three different antennas, a parabolic-, a slot- and a horn antenna, are available. Also, the antenna diagram of the parabolic and the slot. antenna is plotted. For the latter the antenna pattern is measured for two orthogonal planes.

Helix antenna, Polarization theory

Will a right-hand wound helix antenna receive a signal from a left-hand wound helix? What about if the signal first is reflected in a mirror? Is there any difference in the reception from a horn antenna when using a right-hand wound or a left-hand wound helix as receiver? All this is answered in this experiment where polarization theory is studied with the help of two opposite wound helix antennas. Additionally, the antenna pattern and the gain of a helix antenna is measured.

Microstrip antenna, Phased array

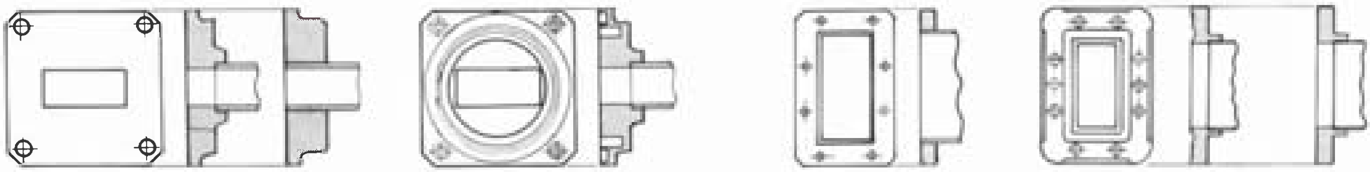
Modern technology represented by a microstrip. antenna is demonstrated in this experiment. The antenna diagram for both the polarization- and the cross-polarization direction is measured and plotted. Using this antenna, consisting of 16 patches, and changing the frequency gives a simple phased array antenna and the experiment is completed with determination of the tilt angle vs. frequency.



Experiment set-up with parabolic antenna.

Flange types

Cover butt sleeve Choke butt Flat sleeve Grooved butt Flat butt



IEC

Waveguide flanges covered by IEC recommendation shall be indicated by a reference number comprising the following information:

a. the number of the present IEC publication.

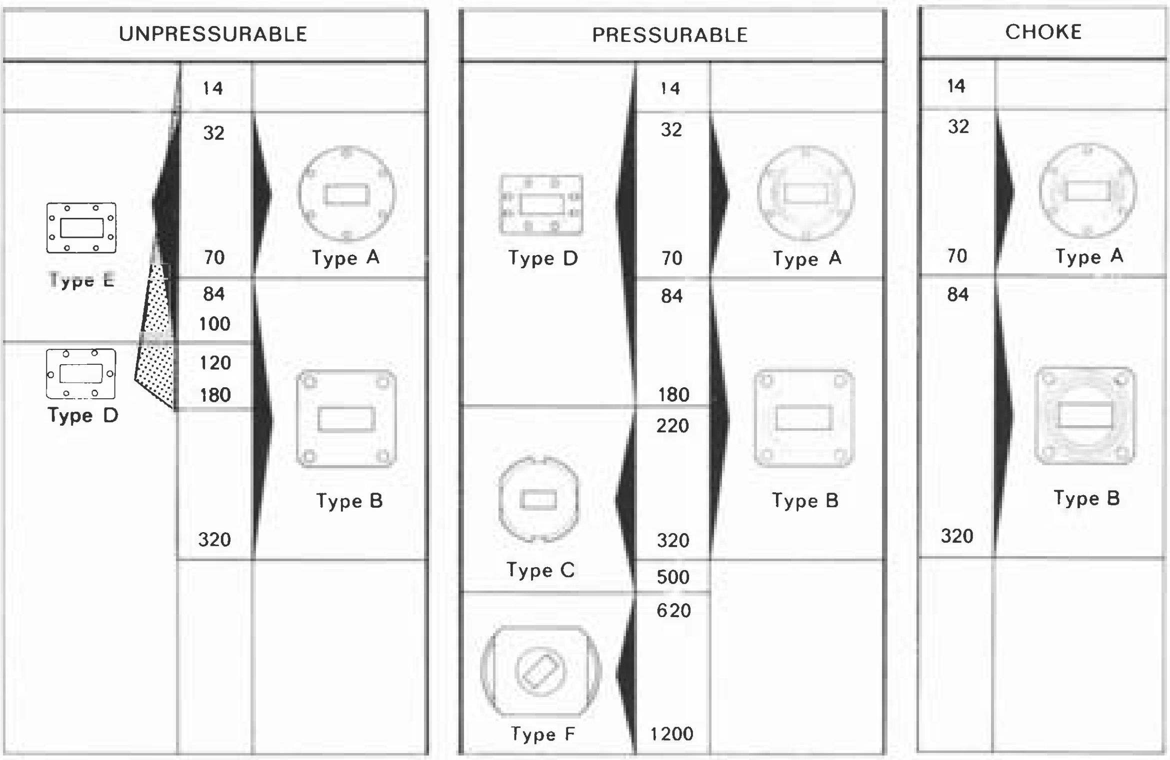
b. the letter "IEC".

c. a dash.

d. a letter relating to the basic construction of the flange
P = pressurable
C = choke, pressurizable
U = unpressurizable.

e. a letter for the type according to the drawing. Flanges with the same letter and of the same waveguide size can be mated.

f. the letter and number of the waveguide for which the flange is designed.



* IEC Recommendations are obtained from:
Central Office of the
International Electrotechnical Commission
1. rue de Varembé
GENEVA, Switzerland

Flange data

Waveguide size	Flange type	Aluminium			Brass	
		MIL F-3922	AN NO, U/G	154-IEC	MIL F-3922	AN NO, U/G
WR 650 (WG 6, R 14)	Flat butt	52-002	1720/U	UDR 14	52-001	1714/U
	Grooved butt	52-024	1343/U	PDR 14	52-023	1362/U
WR 510 (WG 7, R 18)	Flat butt	52-004	1717/U	UDR 18	52-003	1715/U
	Grooved butt	52-026	1719/U	PDR 18	52-025	1718/U
WR 430 (WG 8, R 22)	Flat butt	52-006	1711/U	UDR 22	52-005	1716/U
	Grooved butt	52-028	1345/U	PDR 22	52-027	1344/U
WR 340 (WG 9A, R 26)	Flat butt	52-008	1713/U	UDR 26	52-007	1712/U
	Grooved butt	52-030	1347/U	PDR 26	52-029	1346/U
WR 284 (WG 10, R 32)	Cover sleeve	56-002	584/U	UAR 32	56-001	53/U
	Choke butt	61-001	585A/U	CAR 32	61-002	54B/U
	Flat butt	52-010	1725/U	UDR 32	52-009	1724/U
	Grooved butt	52-032	1349/U	PDR 32	52-031	1348/U
	Flat sleeve	64-002	1484/U	UER 32	64-001	1479/U
WR 229 (WG 11A, R 40)	Flat butt	52-012	1727/U	UDR 40	52-011	1726/U
	Grooved butt	52-034	1351/U	PDR 40	52-033	1350/U
	Flat sleeve			UER 40		
WR 187 (WG 12, R 48)	Cover sleeve	57-001	407/U	UAR 48	57-002	149A/U
	Choke butt	62-001	406B/U	CAR 48	62-002	148C/U
	Flat butt	52-014	1729/U	UDR 48	52-013	1728/U
	Grooved butt	52-036	1353/U	PDR 48	52-035	1352/U
	Flat sleeve	63-005	1480/U	UER 48	63-001	1475/U
WR 159 (WG 13, R 58)	Cover sleeve			UAR 58		
	Choke butt			CAR 58		
	Flat butt	52-016	1731/U	UDR 58	52-015	1730/U
	Grooved butt	52-038	1355/U	PDR 58	52-037	1354/U
	Flat sleeve			UER 58		
WR 137 (WG 14, R 70)	Cover sleeve	55-002	441/U	UAR 70	55-001	344/U
	Choke butt	60-002	440B/U	CAR 70	60-001	343B/U
	Flat butt	52-018	1733/U	UDR 70	52-017	1732/U
	Grooved butt	52-040	1357/U	PDR 70	52-039	1356/U
	Flat sleeve	63-006	1481/U	UER 70	63-002	1476/U
WR 112 (WG 15, R 84)	Cover sleeve	53-004	138/U	UBR 84	53-002	51/U
	Choke butt	59-009	137B/U	CBR 84	59-007	52B/U
	Flat butt	52-020	1735/U	UDR 84	52-019	1734/U
	Grooved butt	52-042	1359/U	PDR 84	52-041	1358/U
	Flat sleeve	63-007	1482/U	UER 84	63-003	1477/U
WR 102	Cover butt	70-002			70-001	1493/U
	Choke butt	69-002			69-001	1494/U
WR 90 (WG 16, R 100)	Cover sleeve	53-003	135/U	UBR 100	53-001	39/U
	Choke butt	59-008	136B/U	CBR 100	59-006	40B/U
	Flat butt	52-022	1737/U	UDR 100	52-021	1736/U
	Grooved butt	52-044	1361/U	PDR 100	52-043	1360/U
	Flat sleeve	63-008	1483/U	UER 100	63-004	1478/U
WR 75 (WG 17, R 120)	Cover sleeve	70-005		UBR 120	70-004	
	Choke butt	59-011		CBR 120	59-010	
	Flat butt			UDR 120		
	Grooved butt			PDR 120		
WR 62 (WG 18, R 140)	Cover sleeve	53-006	1665/U	UBR 140	53-005	419/U
	Choke butt	59-002	1666/U	CBR 140	59-001	541A/U
	Flat butt			UDR 140		
	Grooved butt			PDR 140		
WR 51 (WG 19, R 180)	Cover butt	70-011		UBR 180	70-010	
	Choke butt	69-005		CBR 180	69-004	
	Flat butt			UDR 180		
	Grooved butt			PDR 180		
WR 42 (WG 20, R 220)	Cover sleeve	54-002	597/U	UBR 220	54-001	595/U
	Choke butt	59-004	598A/U	CBR 220	59-003	596A/U
WR 34 (WG 21, R 260)	Coover sleeve	63-010		UBR 260	63-009	1530/U
	Choke butt			CBR 260		
WR 28 (WG 22, R 320)	Coover sleeve			UBR 320	54-003	599/U
	Choke butt			CBR 320	59-005	600A/U

Double-ridge flanges

Waveguide size	Flange type	Aluminium MIL-F-39000/3	Brass MIL-F-39000/3	Holes
WRD 150 D 24	Flat butt	–004	–005	1/4-20 UNC (6X) Ø 6,63 (6X)
WRD 200 D 24	Flat butt	–024	–025	6-32 UNC (4X) Ø 3,68 (4X)
	Flat butt	–026	–027	6-32 UNC (8X)
	Flat butt	–028	–029	Ø 3,68 (8X)
	Grooved butt	–048	–049	6-32 UNC (4X) Ø 3,68 (4X)
	Grooved butt	–050	–051	6-32 UNC (8X)
	Grooved butt	–052	–053	Ø 3,68 (8X)
WRD 350 D 24	Flat butt	–030	–031	6-32 UNC (4X) Ø 3,68 (4X)
	Flat butt	–032	–033	6-32 UNC (8X)
	Flat butt	–034	–035	Ø 3,68 (8X)
	Grooved butt	–054	–055	6-32 UNC (4X) Ø 3,68 (4X)
	Grooved butt	–056	–057	6-32 (8X)
	Grooved butt	-058	–059	Ø 3,68 (8X)
WRD 475 D 24	Flat butt	–036	–037	6-32 UNC (4X) Ø 3,68 (4X)
	Flat butt	–038	–039	6-32 UNC (8X)
	Flat butt	–040	–041	Ø 3,68 (8X)
	Grooved butt	–060	–061	6-32 UNC (4X) Ø 3,68 (4X)
	Grooved butt	–062	–063	6-32 UNC (8X)
	Grooved butt	–064	–065	Ø 3,68 (8X)
WRD 750 D 24	Flat butt	–072	–073	6-32 UNC (2X) Ø 3,68 (2X)
	Flat butt	–074	–075	6-32 UNC (4X)
	Flat butt	–076	–077	Ø 3,68 (4X)
	Grooved butt	–078	–079	6-32 UNC (2X) Ø 3,68 (2X)
	Grooved butt	–080	–081	6-32 UNC (4X)
	Grooved butt	–082	–083	Ø 3,68 (4X)

Waveguide data

Rectangular waveguides

Frequency range GHz	Cut-off freq TE_{10} Mode GHz	Waveguide designation 153-IEC*	British standard	Retma	Jan RG-/U brass	Jan RG-/U alum	Band prefix	Waveguide Inner cross-section 153-IEC* Width mm	Height mm	Tolerance on width and height ±
1.12– 1.7	0.908	R 14	WG 6	WR 650	69	103	L	165.10	82.55	0.33
1.45– 2.2	1.158	R 18	WG 7	WR 510	–	–	D	129.54	64.77	0.26
1.7 – 2.6	1.375	R 22	WG 8	WR 430	104	105	–	109.22	54.61	0.22
2.2 – 3.3	1.737	R 26	WG 9A	WR 340	112	113	–	86.36	43.18	0.17
2.6 – 3.95	2.080	R 32	WG 10	WR 284	48	75	S	72.14	34.04	0.14
3.3 – 4.9	2.579	R 40	WG 11A	WR 229	–	–	A	58.17	29.083	0.12
3.95– 5.85	3.155	R 48	WG 12	WR 187	49	95	G	47.55	22.149	0.095
4.9 – 7.05	3.714	R 58	WG 13	WR 159	–	–	C	40.39	20.193	0.081
5.85– 8.2	4.285	R 70	WG 14	WR 137	50	106	J	34.85	15.799	0.070
7.05–10	5.260	R 84	WG 15	WR 112	51	68	H	28.499	12.624	0.057
7 –11	5.790	–	–	WR 102	–	320	T	25.90	12.95	0.125
8.2 –12.4	6.560	R 100	WG 16	WR 90	52	67	X	22.860	10.160	0.046
10 –15	7.873	R 120	WG 17	WR 75	–	–	M	19.050	9.525	0.038
12.4 –18	9.490	R 140	WG 18	WR 62	91	107	P	15.799	7.899	0.031
15 –22	11.578	R 180	WG 19	WR 51	–	–	–	12.954	6.477	0.026
18 –26.5	14.080	R 220	WG 20	WR 42	53	121	–	10.668	4.318	0.021
22 –33	17.368	R 260	WG 21	WR 34	–	–	–	8.636	4.318	0.020
26.5 –40	21.100	R 320	WG 22	WR 28	96	–	Q	7.112	3.556	0.020

* IEC Recommendations are obtainable from:
Central Office of the International ElectrotechnicaL Commission
1, rue de Varembé
GENEVA, Switzerland

Double-ridge waveguides

Type	Bandwidth ratio 2.4:1 Frequency range GHz	f_{e10} GHz	f_{e20} GHz	Dimensions in mm a	b	d	s
WRD 150 D 24	1.50– 3.60	1.249	3.692	87.76	40.82	17.35	21.95
WRD 200 D 24	2.00– 4.80	1.666	4.925	65.78	30.61	13.00	16.46
WRD 350 D 24	3.50– 8.20	2.915	8.620	37.59	17.48	7.42	9.40
WRD 475 D 24	4.75–11.00	3.961	11.705	27.69	12.85	5.46	6.91
WRD 650 D 28	6.50–18.00*	–	–	18.29	8.15	2.56	4.39
WRD 750 D 24	7.50–18.00	6.239	18.464	17.55	8.15	3.45	4.39
DR 19	7.50–11.00	4.1	–	26.04	12.06	4.85	6.50

* Bandwidth ratio 2.8:1.

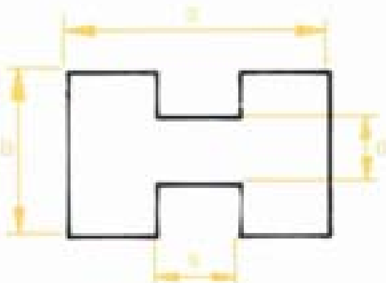
f_{e10} = cut-off frequency for TE_{10}-mode
f_{e20} = cut-off frequency for TE_{20}-mode

Waveguide data

Waveguide Outer cross-section 153-IEC*			Attenuation in dB/m for copper waveguide 153-IEC*			
Width mm	Height mm	Tolerance on width and height ±	Frequency GHz	Theoretical value	Maximum value	Theoretical peak power rating** lowest to highest frequency MW
169.16	86.61	0.20	1.36	0.00522	0.007	12.0 –17.0
133.60	68.83	0.20	1.74	0.00749	0.010	7.5 –11.0
113.28	58.67	0.20	2.06	0.00970	0.013	5.2 – 7.5
90.42	47.24	0.17	2.61	0.0138	0.018	3.4 – 4.8
76.20	38.10	0.14	3.12	0.0189	0.025	2.2 – 3.2
61.42	32.33	0.12	3.87	0.0249	0.032	1.6 – 2.2
50.80	25.40	0.095	4.73	0.0355	0.046	0.94 – 1.32
43.64	23.44	0.081	5.57	0.0431	0.056	0.79 – 1.0
38.10	19.05	0.070	6.46	0.0576	0.075	0.56 – 0.71
31.75	15.88	0.057	7.89	0.0794	0.103	0.35 – 0.46
29.16	16.21	0.125	–	–	–	0.33 – 0.43
25.40	12.70	0.05	9.84	0.110	0.143	0.20 – 0.29
21.59	12.06	0.05	11.8	0.133	–	0.17 – 0.23
17.83	9.93	0.05	14.2	0.176	–	0.12 – 0.16
14.99	8.51	0.05	17.4	0.238	–	0.080– 0.107
12.70	6.35	0.05	21.1	0.370	–	0.043– 0.058
10.67	6.35	0.05	26.1	0.435	–	0.034– 0.048
9.14	5.59	0.05	31.6	0.583	–	0.022– 0.031

** Based on breakdown of air of 15,000 volts per cm (safety factor of approx 2 at sea level)

$f = \sqrt{3} \cdot f_{e10}$	
Attenuation in dB/m for copper waveguide. Theoretical value	Theoretical power handling capacity MW[1)]
0.0194	0.446
0.0298	0.251
0.0696	0.0819
0.109	0.0444
–	–
0.217	0.0178
–	–



1) Based on breakdown of air – 15000 volt per cm (safety factor of approx 2 at sea level) corner radii considered.

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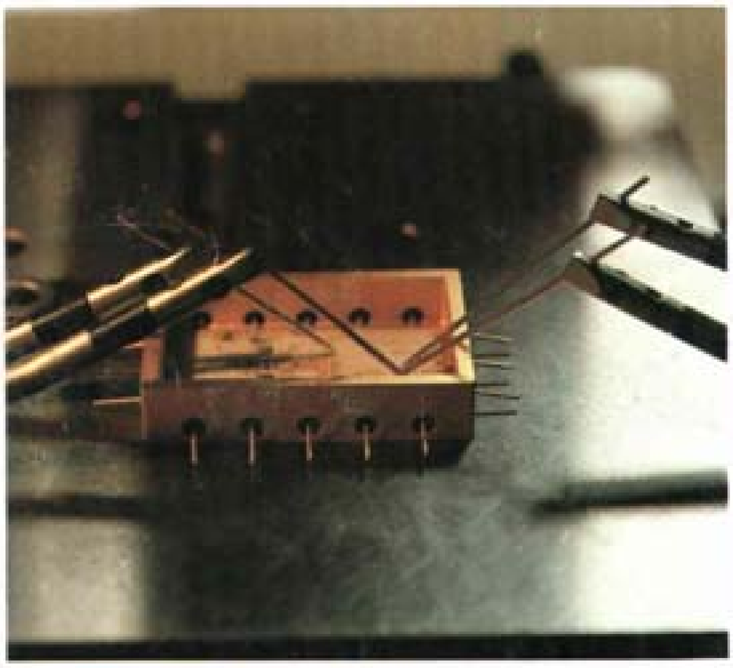

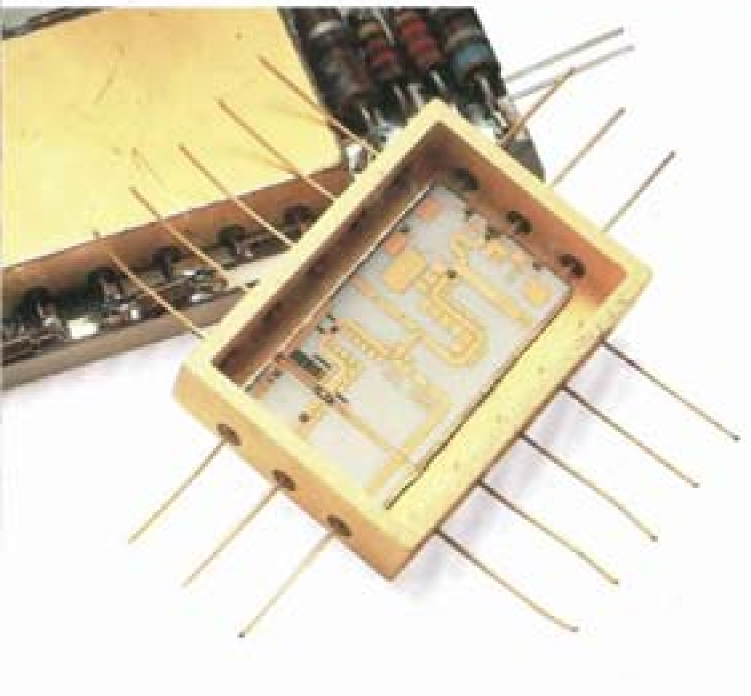

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