TECHNOLOGY SURVEY

TWTs and MPMs

By Ollie Holt

JED's last survey on power amplifiers, which included traveling wave tubes (TWTs) and microwave power modules (MPM)s, appeared in April 2008. In this month's issue, *JED* chose to review the current state of power amplifiers with a focus on TWTs and MPMs used for EW applications and look at their capabilities and limitations. The April 2008 survey focused mostly on solid state power amplifiers. Since the April 2008 survey, very little has changed in TWT and MPM amplifier technology other than some improvements in efficiencies, reliability and increased power output levels. Most of the TWT power amplifiers listed in this survey were developed for radar, radar jamming or communication applications.

The TWT was originally developed by British scientists in 1942-43 in support of creating higher power radar systems for use by the military in World War II. The TWT enabled the radars to transmit at higher RF power levels, enabling the radars to achieve longer detection ranges. The British passed this TWT technology to its US ally.

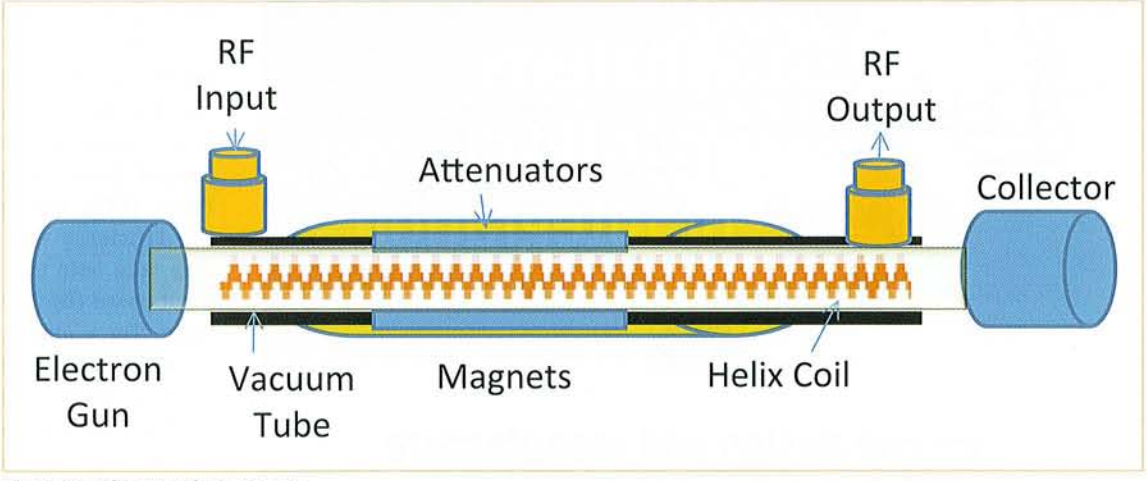


Figure 1: Helix TWT Block Diagram

Figure 1 is a crude block diagram of a Helix TWT. A Helix TWT looks like a long vacuum tube. The electron gun on the left, which is similar to the cathode of a vacuum tube, emits electrons down through the helix wire directed towards the collector. The magnets (yellow tube in **Figure 1**) form a containment field focusing the electron beam down through the helix coil at the collector. The helix coil extends from the RF input to the RF output couplers. The RF input device is a directional coupler, which is used to induce the RF signal to be amplified into the helix coil. It is a directional coupler used in order to direct the input signal toward the collector, not toward the electron gun. As the RF signal travels along the helix coil toward the collector, the electromagnetic field created by the RF current in the helix interacts with the electron beam traveling through the center of the helix, causing a phenomenon called velocity modulation. The electron beam induces more current into the helix as the signal flows through the helix toward the collector causing amplification of the RF signal. The RF output is another directional coupler positioned near the collector. The coupler removes the amplified RF signal from the TWT. The attenuators are

used to prevent reflected RF waves from traveling back down the helix toward the electron gun.

Helix TWTs like the one described above are limited in maximum output power by the current-handling capability of the helix coil. The thickness of the helix wire defines the amount of heating that can occur within the TWT. Overheating (higher power) of the helix wire will cause it to change shape and will impact performance. Thicker helix wire can be used but performance is still limited to about 2.5 kW output power. Thicker wire is harder to machine into the correct shape and retain performance. To increase the output power of a TWT, the helix coil is replaced by a series of coupled cavities spaced along the electron beam to create a helical waveguide. This increases the output power capability to around 60 kW. This type of TWT is referred to as a Coupled Cavity TWT. Most of the TWTs listed in the survey responses are Helix.

Developed in the 1980s and 1990s, the MPM is a hybrid device, combining solid-state and vacuum-tube components. They are typically smaller than a TWT and are used in a wide variety of commercial and military applications. Although TWT's are still the dominant power amplifier device used in EW systems, the use of MPMs is growing.

The survey requested performance information on different parameters that could impact the power amplifier's performance in a desired application. Some of the parameters are operational frequency range, gain or output power, efficiency and dBc. Operational frequency range is almost self explanatory; it just defines the lower to upper frequency range the TWT was designed to operate. Gain defines the increase in power that can be achieved from the input to output power level. The output power defines the maximum output power expected at the maximum gain.

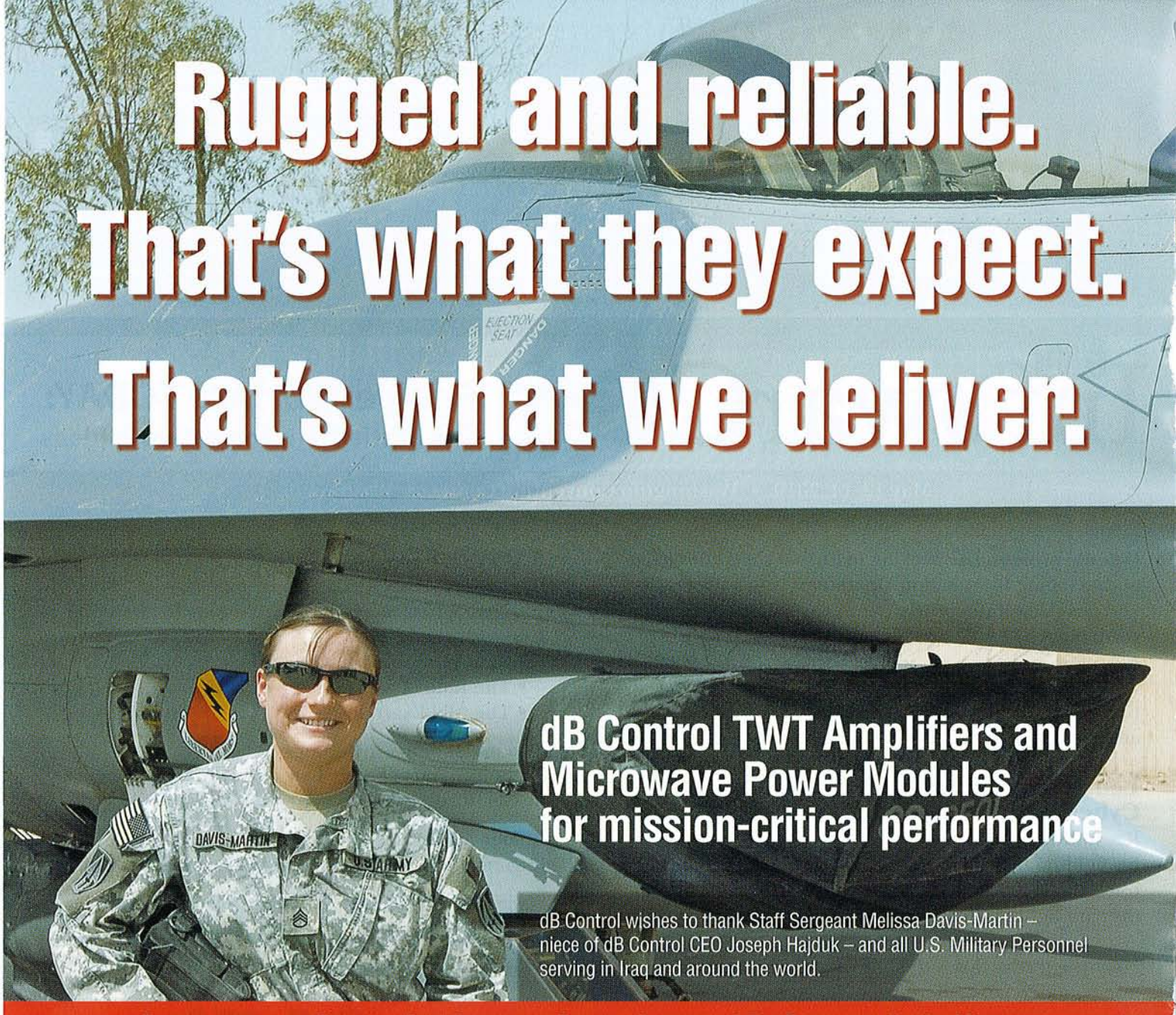
Efficiency is defined as the Power Added Efficiency. Power Added Efficiency is defined as the output power (RF) minus the input power (RF) divided by the DC power. In high-gain systems, the results are about the same as Efficiency (output power {RF} divided by Input Power {DC}), but in low-gain systems the Efficiency can be very different. Also take note that in this survey the input power (DC Power) is average power input. For a pulsed system, the Power Added Efficiency is calculated using the input power DC when the pulse is created, not the average input power DC.

dBc or dB relative to the carrier is a measure of how much higher the carrier (desired) signal is with respect to harmonics or spurious signals created within the device. For most applications the larger this value, the better the performance.

The number of companies manufacturing TWTs and MPMs for EW applications is fairly small. Nine companies (nearly all of the TWT/MPM manufacturers supplying the global EW market) responded to our survey.

JED's next survey, covering Missile Warning Systems, will appear in the May 2010 issue. E-mail editor@crows.org to request a survey questionnaire.

Rugged and reliable. That's what they expect. That's what we deliver.



dB Control TWT Amplifiers and Microwave Power Modules for mission-critical performance

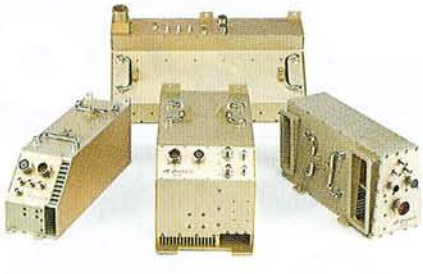
dB Control wishes to thank Staff Sergeant Melissa Davis-Martin – niece of dB Control CEO Joseph Hajduk – and all U.S. Military Personnel serving in Iraq and around the world.

Any spec. Any platform. Any time. dB Control delivers.

When split-second decisions are made under adverse conditions, a failure of the countermeasure system can jeopardize missions and cost lives. Reliable performance of the transmitter in an ECM system cannot be compromised. dB Control keeps you in control by building high performance into every product we deliver.

dB Control provides production-quantity Traveling Wave Tube (TWT) Amplifiers, Microwave Power Modules (MPMs), fully integrated transmitters and power supplies for ground-based, shipborne and high-altitude military manned and unmanned aircraft platforms. And our modular designs enable us to quickly configure custom products to your exact specifications.

We design and manufacture rugged, reliable microwave power systems for the U.S. Armed Forces and key OEMs – customers that demand performance. If your expectations are just as high, contact us today.



dB Control
Reliability by Design™

Go to **www.dBControl.com/JEDoffer** to download your free copy of our latest technical whitepaper on TWT amplifiers.

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TECHNOLOGY SURVEY: TWTs and MPMs

MODEL	TYPE	OP FREQ. RANGE	INPUT POWER (W)	OUTPUT POWER/GAIN	EFFICIENCY (%)
CPI; Palo Alto, CA, USA; +1-650-846-3900; www.cpii.com					
VTF-6132	TWT	2-8 GHz	450 W	100 W CW/28 dB	*
VTM-5114	TWT	6-18 GHz	500 W	1.0-1.25 kW Peak/38 dB	*
VTM-6199	TWT	7.5-18 GHz	510 W	95-140 W CW/38 dB	*
VTF-6130	TWT	2.0-6.5 GHz	650 W	100-200 W CW/26 dB	*
dB Control; Fremont, CA, USA; +1-510-656-2325; www.dBControl.com					
dB-3749	TWT	6-18 GHz	300 W Typical	1000 W Peak at 6% Duty	20%
dB-4118	MPM	6-18 GHz	300 W Typical	100 W CW	20%
dB-4210	MPM	2-7 GHz	450 W Typical	200 W CW	20%
dB-3758	TWT	X Band or Ku Band at 1-3 GHz Bandwidth	250 W Typical	1000 W Peak at 6% Duty	20%
dB-4102/4103-S	TWT	18-26 GHz and 26-40 GHz	150 W Typical	40 W CW/Pulse	20%
e2v; Chelmsford, Essex, UK; +44 (0)1245 453607; www.e2v.com					
Flagship 4.8kV Mini TWT, Model N20181	TWT	4.5-18 GHz	580 W Max Prime Power	160 W (100 W minimum across the full band)/67 dB (45 band edges)	40% (18% band edges)
High Power 6.2kV Midi TWT, Model N10110	TWT	6-18 GHz	1000 W Max Prime Power	260 W (180 W band edges)/65 dB (38 dB band edges)	26% (18% band edges)
Standard 4.5kV Mini TWT, Model N20160	TWT	4.5-18 GHz	470 W Max Prime Power	140 W (50 W at 4.5 GHz, 100 W at 18 GHz)/60 dB (36 dB band edges)	36% (11% band edges)
Low Power 4.5kV Mini TWT, Model N10172	TWT	4.5-18 GHz	430 W Max Prime Power	125 W (25 W at 4.5 GHz, 75 W at 18GHz)/53 dB (33 dB band edges)	32% (6% band edges)
L-3 Communications EDD East; Williamsport, PA, USA; +1-570-326-3561; www.l-3com.com/edd					
TXI-1002	TWT-based Transmitter	I Band, 10 GHz	2 kW Max	500 W	25%
L-3 Communications EDD West; San Carlos, CA, USA; +1-650-591-8411; www.l-3com.com/edd					
L6134	TWT	6-18 GHz	430 W	53 dBm	>40%
M1201	MPM	2-6 GHz	375 W	49 dBm	40%
M1225	MPM	6-18 GHz	425 W	52 dBm	30%
M1300	MPM	26-40 GHz	350 W	48 dBm	>30%
M1282	MPM	26-40 GHz	350 W	48 dBm	>30%

LEVELS (dBc)	RELIABILITY	SIZE (HxWxL inches)	WEIGHT (lb/kg)	FEATURES
*	*	1.65 x 1.6 x 11.4 in.	2.0 lbs	*
*	*	1.75 x 2.0 x 12.8 in.	2.7 lbs	*
*	*	1.25 x 1.9 x 10.0 in.	2.0 lbs	*
*	*	1.78 x 1.8 x 13.4 in.	2.3 lbs	*
-10 dBc Harmonics; -55 dBc Spurious	>10000 Hours for Military Airborne Environment	17.7 x 6.5 x 5 in.	33 lbs	Used in airborne EW systems. Qualified for military airborne environment.
-10 dBc Harmonics; -55 dBc Spurious	>10000 Hours for Military Airborne Environment	11 x 8 x 1.6 in.	6 lbs	Built-in pulse modulation capability at 250 kHz PRF. Used in Electronic Countermeasure (ECM) systems.
-5 dBc Harmonics; -55 dBc Spurious	>10000 Hours for Military Airborne Environment	13.75 x 7 x 2.5 in.	12 lbs	Used in Electronic Countermeasure (ECM) systems.
-12 dBc Harmonics; -60 dBc Spurious	>10000 Hours for Military Airborne Environment	12 x 9.6 x 4 in.	17 lbs	Used in Airborne Radar Applications (SAR, Multi-Mode, etc). Excellent phase noise and spurious, digital control. Built-in cooling.
-20 dBc Harmonics; -50 dBc Spurious	>10000 Hours for Ground Mobile Environment	18.5 x 12 x 10 in.	60 lbs	Environmentally sealed unit used in ground-mobile EW systems. Built-in cooling and remote control feature.
0 dBc at 4.5 GHz; -10 dBc at 9 GHz	Typical EW Environment 9000 Hours MTBF	1 x 1 x 9.5 in.	320 g	Optional - Focus Electrode, TNC or Waveguide OP
-2 dBc at 6 GHz; -7 dBc at 9 GHz	Typical EW Environment 9000 Hours MTBF	2.5 x 2 x 13 in.	1.4 kg	Optional - Focus Electrode
2 dBc at 4.5 GHz; -14 dBc at 9 GHz	Typical EW Environment 9000 Hours MTBF	1 x 1 x 9 in.	300 g	Optional - Focus Electrode, SMA, TNC or Waveguide OP
3 dBc at 4.5 GHz; -8 dBc at 9 GHz	Typical EW Environment 8000 Hours MTBF	1 x 1 x 8.5 in.	300 g	Optional - Focus Electrode, SMA, TNC or Waveguide OP
-30 dBc	10000 Hours	16 x 24 x 24 in.	250 lbs	Turnkey TWT-based transmitter for radar simulation and training used on JTE, Mutes and Mini-Mutes mobile platforms.
Harmonic -6 dBc; Spurious -60 dBc	>9700 Hours	1.5 x 1.5 x 10 in.	< 2 lbs	Production released item available as a stand-alone TWT, packaged with a pre-amp driver (option), and fully integrated (option) into an MPM. Consult factory with special power or frequency requirements.
Harmonic -7 dBc; Spurious -45 dBc	>12000 Hours	1.25 x 7 x 10.75 in.	< 8 lbs	Production released item, multiple packaging/ power options available including active cooling heat exchanger system. Consult factory for special power or frequency requirements.
Harmonic -4 dBc; Spurious -45 dBc	12000 Hours	1.40 x 7.75 x 8 in.	< 6.5 lbs	Production released item, multiple packaging/ power options available including active cooling heat exchanger system. Consult factory for special power or frequency requirements.
Harmonic -15 dBc; Spurious -30 dBc	12000 Hours	1.40 x 7.75 x 8 in.	< 7.5 lbs	Totally self contained with integral cooling, multiple packaging/power options available. Consult factory for special power or frequency requirements.
Harmonic -15 dBc; Spurious -40 dBc	12000 Hours	1.25x 7.5 x 8.5 in.	< 6 lbs	Production released item, multiple packaging/ power options available including active cooling heat exchanger system. Consult factory for special power or frequency requirements.

TECHNOLOGY SURVEY: TWTs and MPMs

MODEL	TYPE	OP FREQ. RANGE	INPUT POWER (W)	OUTPUT POWER/GAIN	EFFICIENCY (%)
MITEQ, Inc.; Hauppage, NY, USA; +1-631-439-9469; www.miteq.com					
MT4100-535-2.5/7.5	MPM	2.5-7.5 GHz	3000 W	500 W (57.0 dBm)/60 dB	17%
MT4100-450-2/8	MPM	2-8 GHz	3000 W	370 W (55.7 dBm)/60 dB	17%
MT4100-300-6/18	MPM	6-18 GHz	1900 W	250 W (53.7 dBm)/60 dB	13%
MT3100-INS-50-18/26.5	MPM	18-26.5 GHz	600 W	40 W (46.0 dBm)/46 dB	7%
MT3100-INS-50-26.5/40	MPM	26.5-40.0 GHz	600 W	40 W (46.0 dBm)/56 dB	7%
MT3100-INS-40-18/40	MPM	18.0-40.0 GHz	600 W	33 W (45.2 dBm)/56 dB	7%
Teledyne MEC; Rancho Cordova, CA, USA; +1-916-638-3344; www.teledyne-mec.com					
MEC 5196	TWT	2.0-8.0 GHz	1850 W	450 W/26 dB min/46 dB max	26%
MEC 5411	TWT	6.5-18.0 GHz	1400 W	300 W/35 dB min/45 dB max	25%
MEC 5496	TWT	26.5-40.0 GHz	500 W	100 W/35 dB min/50 dB max	20%
MTG 3041	TWT	2.0-8.0 GHz	750 W	2000 W/38 dB min/58 dB max	24%
MTI 3444	TWT	6.5-18.0 GHz	950 W	1580 W/43 dB min/46 dB max	14%
Thales Electron Devices; Velizy-Villacoublay, France; +33 (0)1 30 70 36 40; www.thalesgroup.com					
TH24445B	MPM	4.5-18 GHz	*	100 W	30%
TH24475	MPM	2 GHz in 13.5-18 GHz	*	110 W	30%
TH4443E	TWT	4.5-18 GHz	*	8 kW/400 W	30%
TH4428	TWT	18-40 GHz	*	200 W	30%
TH4428	TWT - Helix TWT	18-40 GHz	*	80 W	30%
TMD Technologies Ltd.; Hayes, Middlesex, UK; +44 (0)20 8573 5555; www.tmdtechnologies.co.uk					
PTX8340	MPM	2.0-8.0 GHz	*	100 W	*
PTX8200	MPM	4.5-18.0 GHz	*	100 W	*
PTX8207	MPM	4.5-18.0 GHz	*	140 W	*
PTX8320	MPM	26.0-40.0 GHz	*	50 W	*
Triton Services Electron Technology Div.; Easton, PA, USA; +610-252-7331, www.tritonetd.com					
F-2454	TWT	2.3-7.0 GHz	750	200 W	30
F-2491	TWT	2-6 GHz	660	100-250 W	30
F-9106A	MPM	6-18 GHz	365	50-100 W	33
F-9107A	MPM	2-6 GHz	390	75-100 W	33
F-2153	TWT	2-4 GHz	*	1500 W	*

LEVELS (dBc)	RELIABILITY	SIZE (HxWxL inches)	WEIGHT (lb/kg)	FEATURES
-60 dBc Spurious/-4 dBc Harmonic	35000 Hours	8.75 x 19 x 24 in.	90 lbs/41 kg	Atten, meters, Ethernet, etc
-60 dBc Spurious/-4 dBc Harmonic	35000 Hours	8.75 x 19 x 24 in.	90 lbs/42 kg	Atten, meters, Ethernet, etc
-60 dBc Spurious/-4 dBc Harmonic	35000 Hours	5.25 x 19 x 24 in.	65 lbs/30 kg	Atten, meters, Ethernet, etc
-60 dBc Spurious/-8 dBc Harmonic	35000 Hours	11.8 x 9.6 x 20.5 in.	47 lbs/21.4 kg	Atten, meters, Ethernet, etc
-60 dBc Spurious/-8 dBc Harmonic	35000 Hours	11.8 x 9.6 x 20.5 in.	47 lbs/21.4 kg	Atten, meters, Ethernet, etc
-60 dBc Spurious/-8 dBc Harmonic	35000 Hours	11.8 x 9.6 x 20.5 in.	47 lbs/21.4 kg	Atten, meters, Ethernet, etc
*	40000-120000 Hours MTBF (depending on the environment)	approx. 4 x 4 x 24 in.	9.0 lbs/4.1 kg	ITAR
*	40000K-120000 Hours MTBF (depending on the environment)	approx. 4 x 4 x 24 in.	9.0 lbs/4.1 kg	ITAR
*	4000-10000 Hours MTBF (depending on the environment)	approx. 4 x 4 x 24 in.	7.5 lbs/3.4 kg	ITAR
*	40000-120000 Hours MTBF (depending on the environment)	approx. 4 x 4 x 24 in.	8.0 lbs/3.6 kg	ITAR
*	40000-120000 hours MTBF (depending on the environment)	approx. 4 x 4 x 24 in.	7.0 lbs/3.2 kg	ITAR
*	*	1.38 x 9.1 x 9.84 in.	6.4 lbs	*
*	*	1.38 x 9.1 x 9.84 in.	6.4 lbs	*
*	*	1.2 x 1.8 x 8.7 in.	1.6 lbs	*
*	*	1.65 x 1.61 x 9.4 in.	1.6 lbs	*
*	*	1.65 x 1.61 x 9.4 in.	1.6 lbs	*
*	High	280 x 200 x 32 mm	3.5 kg	CW/pulsed
*	High	260 x 200 x 32 mm	4.0 kg	CW/pulsed
*	High	260 x 200 x 32 mm	4.0 kg	CW/pulsed, low noise
*	High	250 x 200 x 40 mm	4.0 kg	CW/pulsed
-60	*	2.6 x 2.75 x 14.0	2 lb/0.9 kg MAX	3 minute warm-up, 5-stage collector, shadow grid any duty + CW conduction cooled, up to 70,000 ft altitude
-60	*	2.0 x 2.0 x 12.5	3.2 lb/1.45 kg MAX	3 minute warm-up, 3-stage collector, non-intercepting grid any duty + CW conduction cooled, up to 70,000 ft altitude
-40	*	2.5 x 6.2 x 7.1	6.0 lb/2.7 kg	2 minute warm-up, CW operation, self-contained air cooling, up to 40,000 ft altitude, prime power 28 VDC
-40	*	2.4 x 5.0 x 11.5	8.0 lb/3.6 kg	2 minute warm-up, CW operation, self-contained air cooling, up to 40,000 ft altitude, prime power 28 VDC
-40	*	2.4 x 3.6 x 17.25	7.5 lb/3.4 kg	3 minute warm-up, 4% duty max, air cooled, up to 60,000 ft altitude

Survey Key – TWTs and MPMs

MODEL

Product name or model number

TYPE

TWT or MPM

- TWT = travelling wave tube
- MPM = microwave power module

OP. FREQ. RANGE

Operating frequency range in KHz, MHz or GHz

INPUT POWER

In Watts

OUTPUT POWER/GAIN

P1 dB or gain in dB

EFFICIENCY

Power Added Efficiency in percent

LEVELS

Harmonic and spurious levels in dBc

RELIABILITY

Mean time between failures in thousands of hours

- MTBF = mean time between failures

SIZE

H x W x L in inches

WEIGHT

Weight in lb/kg

FEATURES

Any power-up cycle required, amplifier class, special cooling requirements and breakdown voltage

- PRF = pulse recurrence frequency
- SAR = synthetic aperture radar
- TNC = Threaded Neill Concelman
- SMA = sub-miniature type A
- CW = continuous wave
- RF = radio frequency
- ITAR = International Traffic in Arms Regulations

OTHER ABBREVIATIONS USED

- opt = option/optional
- dep = dependent
- config = configuration
- wband = wideband
- nband = narrowband
- < = greater than
- > = less than
- min = minimum
- max = maximum
- deg = degree
- freq = frequency

** Indicates answer is classified, not releasable or no answer was given.*

OTHER COMPANIES

This reference list includes websites for additional companies in the field that were unable to provide survey information due to security constraints or publication deadlines, or that declined to participate.

Company Name	Website
NEC	www.nec-mwt.com

May 2010 Product Survey: Missile Warning Systems

This survey will cover passive and active missile warning systems. Please e-mail editor@crows.org to request a survey.