

Satcom Transceiver Delivers Linear 13 W

This highly integrated microwave assembly employs advanced SMT fabrication techniques to reduce size, weight, and power to previously unattainable levels.

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Frequency upconverter/downconverter subsystems designed for satellite communications (satcom) terminals tend to be larger than the ever-shrinking units for terrestrial consumer wireless systems. Ruggedized equipment for military satcom systems is larger still. However, as demonstrated by the model 81000 satcom transceiver subsystem from Narda Microwave-East (www.nardamicrowave.com), innovative approaches to design and fabrication can dramatically reduce the size, weight, and power consumption of even military satellite terminals. In a housing measuring just 15 x 6.25 x 3.25 in., and weighing only 15 lb., the model 81000 not only packs frequency upconverter and downconverter subsystems, but a 13-W linear RF power amplifier, a power supply, control circuits, and Ethernet and RS-485 connectivity.

Model 81000 (**Fig. 1**) is designed for use on platforms ranging from fixed-wing aircraft and helicopters to UAVs and ground vehicles to man-portable applications when operated from the integrated battery pack. The design of the unit is based on a combination of Narda-developed advances in microwave-integrated-circuit (MIC) and surface-mount technologies that allow Integrated Microwave Assemblies (IMAs) to surpass the mechanical and electrical capabilities of conventional integrated assemblies. Model 81000 is an L-band/Ku-band unit, with models covering X- and Ka-band satcom bands available as well.

The design of the assembly was based on a set of custom specifications that encompassed performance, size, weight, power consumption, and ruggedness. Designers at Narda performed a system flow-down analysis from which an architecture consisting of four functional blocks emerged—a block upconverter (BUC), block downconverter (BDC), solid-state power amplifier (SSPA), and DC power and control subsystem. Each functional block was assigned performance specifications based upon the system flow-down analysis, designed and developed independently and finally integrated at the top system-level assembly. The BUC, BDC, SSPA, control circuits, and power supply are shown in **Fig. 2**.



1. Model 81000 is a satcom transceiver mounted in a rugged enclosure measuring 15 x 6.25 x 3.25 in., and weighing a manageable 15 lb.

The upconverter and downconverter modules in the L-band/Ku-band model 81000 were largely designed and fabricated using what the company calls its “Ultimate SMT” technology, which has been successfully utilized at frequencies through 31 GHz. This technology has several advantages. There is no housing of the type typically associated with MIC construction but rather a single multilayer board formed of various microwave laminates. Higher-frequency components are on the top side of the board (**Fig. 3**), with lower-frequency devices and control and digital circuits on the bottom side (**Fig. 4**). Blind and through vias achieve grounding and interconnections between layers.

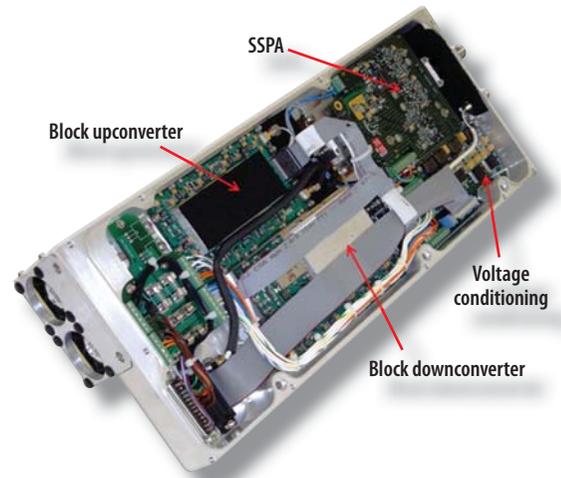
The use of controlled-depth, machined pockets on the top side of the board between metallized layer 1 (RF signal) and layer 2 (RF ground) helps optimize performance. The controlled-depth routing process ensures that the machined pockets do not protrude into the ground layer by more than 10 to 20 μm . Standard MIC-type components, such as bare die and alumina filters, are inserted into the pockets. Layer 2 can be considered the ground plane of a conventional single-layer assembly, which the technique mimics. A microstrip line on the top layer is wire-bonded directly to the component in the pocket and then back to the microstrip line on the other end, maintaining single-layer ground connectivity.

With conventional SMT techniques, signal and ground paths must transition to and from the device using vias, which introduce discontinuities and reduce the level of achievable performance, especially at higher frequencies. By eliminating these transitions, designers can exert more control over performance, which in the case of a filter is essential as transitions and their inevitable discontinuities affect the filter’s rejection and return loss characteristics. This technique allows the designer the flexibility to utilize both MIC and SMT simultaneously, taking advantage of the benefits that each technology offers.

The bottom side of the BUC and BDC boards contains the reference oscillator section, the lower-frequency portion of the synthesizer, including the main and offset loops, and DC and control circuits. The output of the main loop is fed to the top side of the board using a through-board transition, after which it is multiplied to the desired higher-frequency range, filtered to reduce spurious content, amplified, and applied to the LO port of the respective mixer.

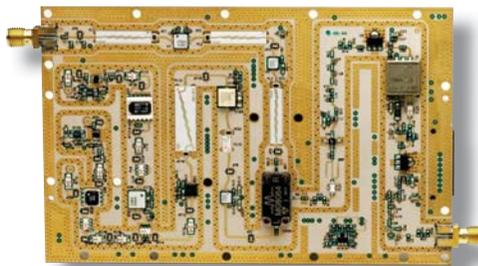
The top side of the board incorporates ground via “fencing” strategically placed in a pattern to isolate areas that either create or are sensitive

2. The transceiver is constructed of four modules: two converters, a 13-W linear RF power amplifier, and a module containing control and a DC/DC converter.

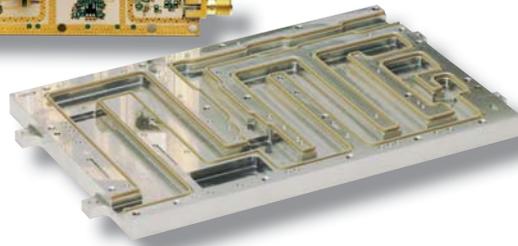


The Model 81000 transceiver at a glance.

RECEIVE BLOCK UPCONVERTER	
Input frequency range (GHz)	11.45 to 12.75 (10.95 to 12.75)
Output frequency range (MHz)	950 to 1450 (950 to 1700)
Downconversion bands (GHz) (others available)	11.45 to 11.95 11.8 to 12.3 12.25 to 12.75
Gain, minimum (dB)	35
Input power (dBm)	-95 to -30
Noise figure (dB)	15
Frequency reference (MHz)	10, internal or external
TRANSMIT BLOCK UPCONVERTER	
Input frequency range (MHz)	950 to 1700
Output frequency range (GHz)	13.75 to 14.5
Gain, minimum (dB)	58
Noise figure (dB)	20 (7 optional)
SOLID-STATE RF POWER AMPLIFIER	
Linear RF output power at -26 dBc spectral regrowth, one symbol offset from carrier (dBm, W)	+41.14, 13
OTHER SPECIFICATIONS	
DC input power (VDC)	+48
DC input current, maximum (ADC)	4.0 at Plin
Communications interfaces	Ethernet, RS-485
Dimensions (in.)	15 x 6.25 x 3.25
Weight (lb.)	15
Operating temperature range (°C)	-30 to +55



3. The block downconverter is implemented on a two-side multilayer circuit board. The high-frequency side shown here includes via fencing that isolates areas that radiate or are sensitive to high-frequency energy and interconnects layer 1 and 2 ground plane metallization. A form-in-place gasket shown on the cover provides EMI shielding.



to radiated emissions. The vias interconnect the layer 1 and layer 2 ground plane metallization and mate with a channelized cover containing a conductive form-in-place (FIP) gasket that is compressed between the body of the module and the cover to provide a high level of EMI shielding (*Fig. 3*). The cover acts as a heat-transfer surface to pull heat from the board to the cover where it is dissipated via a heat sink. Earlier designs did not use an FIP gasket and required a large number of screws to secure the cover. Eliminating the screws and replacing them with vias and EMI compression gasketing reduced size by at least 40 percent, weight by about 30 percent, and simplified assembly as well.

The four-stage, 13-W linear (20-W output power at 1-dB compression) SSPA (*Fig. 5*) uses internally matched GaAs MES-FETs in Class AB operation for balance among power output at 1-dB compression, maximum linear power (defined as the power at which the spectral regrowth, measured at a one symbol rate offset, reaches a predetermined maximum), and DC power consumption. During the design phase, each internally matched device was evaluated to

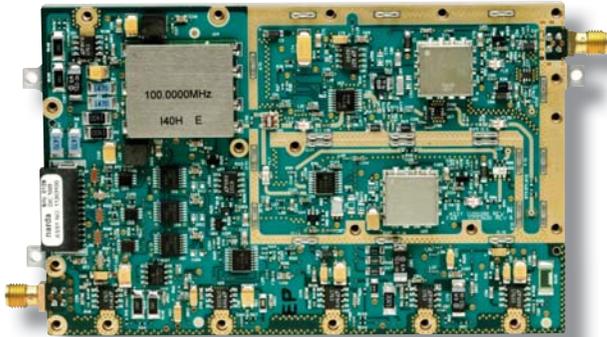
determine its spectral regrowth and 1-dB compression performance versus quiescent drain current. The bias point that optimized each of these critical parameters was used in the system.

The devices are mounted into the SSPA housing using a soldering approach to minimize the electrical discontinuities between the device package and the input/output microstrip transmission lines. The solder also provides a good thermal interface between the device and the housing, lowering junction temperature and increasing reliability.

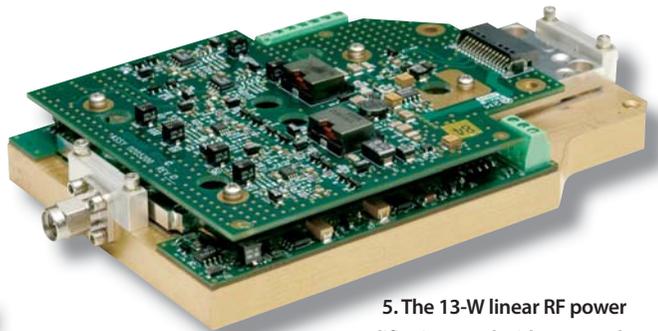
Surface-mount MMIC devices are employed as gain stages, and temperature-sensitive attenuator pads are used to provide a degree of temperature compensation. However, system-level temperature compensation is accomplished by microprocessor-controlled voltage-variable attenuators (VVAs) in the BUC and BDC modules. Printed-circuit filters are also included to provide harmonic and local oscillator rejection. Finally, a diode detector after the final output stage of the SSPA offers precise power level detection capability.

Bias control in the SSPA is

accomplished using several novel techniques. A combination of digitally controlled potentiometers, HEXFET switches for independent drain voltage on/off control, and built-in drain current monitoring circuitry, are incorporated to set the bias points of each output device. During factory alignment, each output device is turned on individually and its digital potentiometer is adjusted through use of automated test equipment to establish optimal bias points. The automatic alignment is repeated at multiple temperatures, the result of which is stored in a calibration look-up table in the RF amplifier module. At run time, the microcontroller reads the temperature and calibration data from the power amplifier and adjusts the digital potentiometers accordingly. This unique biasing technique eliminates the more conventional process of manually measuring drain current and adjusting a potentiometer or iteratively replacing select-at-test resistors to establish proper biasing. As a result, the power amplifier can be aligned in less time, with better precision, and with more consistent performance over temperature. The microcontroller and power



4. This view shows the downconverter's low-frequency, control, and power functions.



5. The 13-W linear RF power amplifier is mated with a control board that provides microcontroller I/O, gate bias, temperature monitoring, power detection, regulation, and filtering functions.

distribution board responds to commands from a host computer, incorporates self-protection functionality, reports health and status information to the host computer, provides temperature-compensated gain control for each RF module, and in the Ka-band version, adjusts the power amplifier's operating points as a function of temperature.

Power supply voltages, synthesizer lock detect outputs, power amplifier drain currents, and detected RF power output are all continuously monitored. If either synthesizer goes into an out-of-lock condition, the transmitter is taken off the air to prevent interference with other users. If the drain current of any output device exceeds a safe level, or if an attempt is made to drive the SSPA power output beyond a safe level, the transmitter is shut down to prevent damage.

The microcontroller reads the temperature sensors and

calibration look-up tables that are resident in all three RF modules and adjusts the VVAs in each RF module. Temperature and calibration data are combined with host system command data to provide adjustable gain and maintain constant gain over temperature. In addition to providing control functions, the microcontroller and power distribution board convert the "raw" +48-VDC input power into regulated and filtered +12 and +6.5 VDC supply voltages required by the RF modules.

The four-module assembly has a finned heat sink and two fans for cooling. The SSPA is mounted to the "cool" side of the heat sink furthest from the fans. Fan speed is controlled automatically, although it can be reprogrammed for specific applications. The assembly has an environmental seal between the cover and the housing and a Gore-Tex vent to allow air but

not moisture to pass through the unit.

Model 81000 is available in the standard configuration with the performance shown in the table, or in X-band and Ka-band configurations to serve these other satcom bands. Construction in the case of the Ka-band converter employs Narda "Ultimate MIC" approaches, which are similar in many respects to the Ultimate SMT techniques described above but contain a higher degree of MIC content.

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