A PRODUCTION 30-KW, L-BAND SOLID-STATE TRANSMITTER

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Abstract

A 30-kW, L-Band Solid-State Transmitter has been designed for the look-down radar used on a tethered aerostat system deployed to combat drug smugglers. This transmitter replaces a tube transmitter previously used in this type radar which results in significantly improved reliability, maintainability, availability, and a 30 percent decrease in overall transmitter weight.

Solid-state transmitter technology has long been credited with advances in the state-of-the-art in reliability, maintainability, and availability by using solid-state transistors in place of RF tube amplifiers. As RF transistor power capability has increased, so has the potential for use in higher power applications. Solid-state transistor amplifiers have gradually been breaking into high power RF systems previously dominated by tube amplifiers, to the current point where 100 percent solid-state high power transmitters are practical. The new transmitter described in this paper combined with existing TPS-63 radar hardware forms the basis for the LASS tethered aerostat system. The first of several systems is currently in use by the United States Customs Service at Fort Huachuca to combat drug smugglers.

The radar is located in a wind screen below a 245-foot aerostat weighing 12,750 pounds (figure 1). The radar consists of several electronics cabinets (figure 2), and an antenna which are mounted back-to-back and rotated as an assembly inside the wind screen. The air cooled solid-state transmitter is housed in a single cabinet, where the previous tube versions required two cabinets for the high power tube amplifiers, as well as a separate liquid-to-air heat exchanger. The solid-state transmitter delivers a 100 μsec, 30-kW, peak power pulse at 4 percent duty factor over the instantaneous band of 1215 to 1350 MHz. The high output power is achieved by combining 72 power modules (288 transistors) operating in parallel. These modules provide a high degree of redundancy, high availability, and fail-soft operation. This fail-soft operation, or graceful degradation, allows mission continuity even with multiple transistor failures, and an MTBF of over 5500 hours. Periodic scheduled

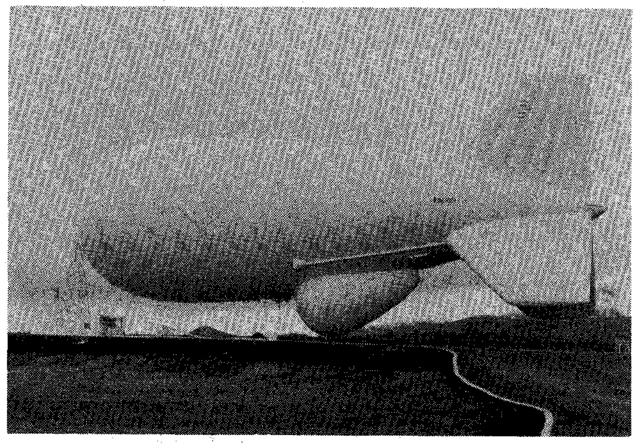


Figure 1

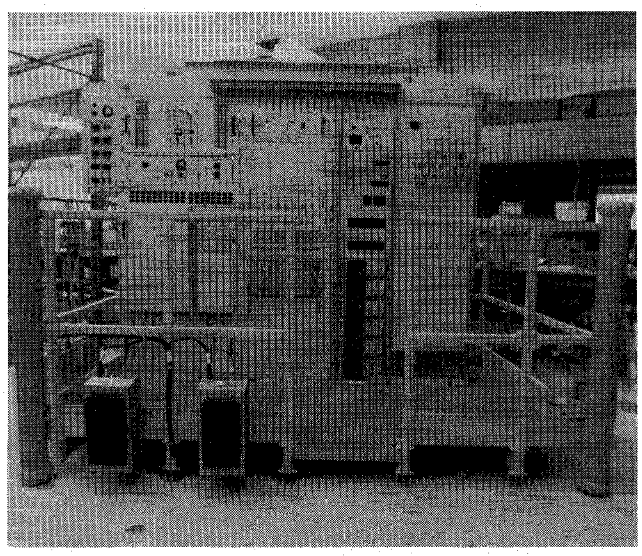


Figure 2

maintenance provides almost 100 percent availability.

The radar also features high MTI stability for excellent clutter rejection. The transmitter MTI improvement factor of over 66 dB is accomplished by careful regulation of the transistor bias supplies. The stability is also enhanced by the use of switcher type power supplies operating non-coherently to recharge the output storage capacitor banks.

The transmitter (figure 3) consists of four slide out amplifier panels, two preamplifiers, six power supplies, a control section, splitters, combiners, and a blower assembly.

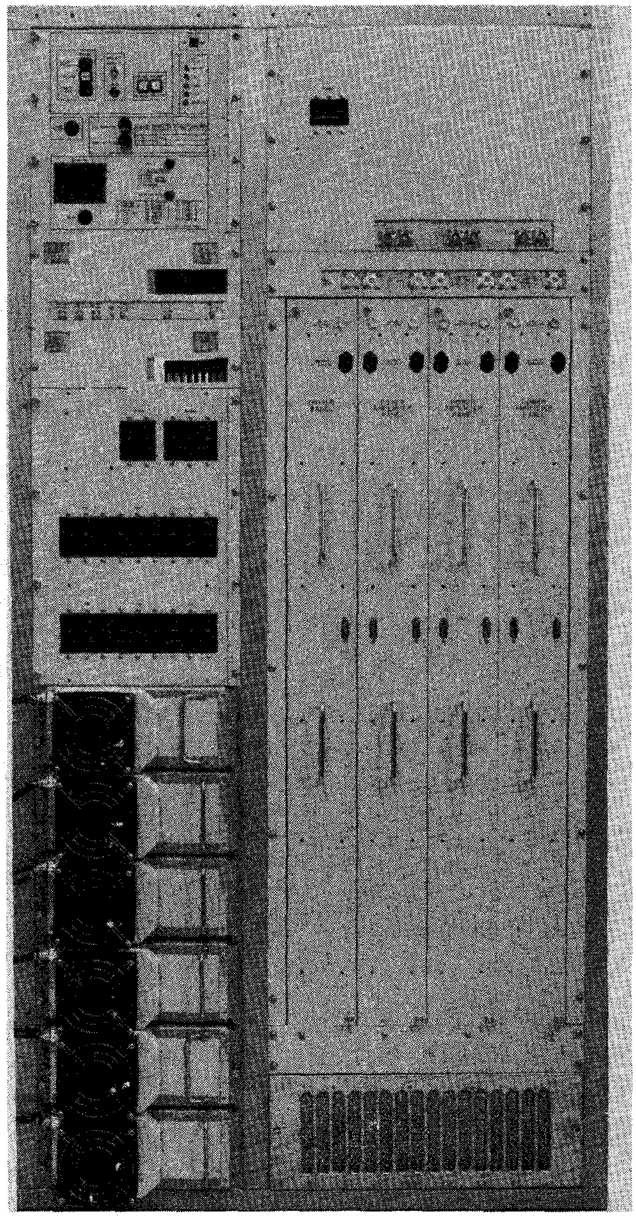


Figure 3

The entire transmitter is contained within a single 72 inches high x 36 inches wide x 24 inches deep cabinet. The transmitter is configured for quick, easy removal of all assemblies to minimize the time required for maintenance. The modular assembly also lends itself to variations with different power requirements.

The transmitter block diagram is shown in (figure 4). The input from the radar frequency generator is split to feed the two preamplifiers. One preamplifier is active supplying 460 watts peak power to the driver amplifier, while the other preamplifier is in standby for enhanced reliability. A coaxial switch and automatic preamplifier selection circuitry are used to select the active preamplifier output. The driver stage features automatic level control for derated operation at 3.0 kW, which is then split six ways to feed the six power amplifier inputs. The power amplifier output stages are combined in low-loss, air dielectric stripline and provides 30-kW minimum output power, with a combining efficiency of 69 percent. The individual transistor dc to RF efficiency is typically 50 percent. Additional control circuitry provides diagnostic information for performance monitoring, protection circuitry, and maintenance requirements.

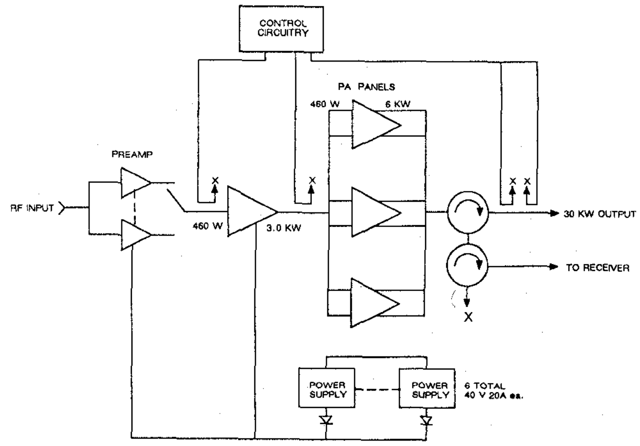


Figure 4

The two preamplifier assemblies provide nearly 32 dB of gain from 7 stages of transistor amplification. The first 3 stages are operated in class A for initial amplification and overdrive protection. Two balanced class C stages drive the last two stages which utilize a power module identical to the module used in the driver and power amplifiers. The power module produces 460 watts at reduced bias voltage for excellent reliability, and the redundant preamplifier provides even greater system level reliability. The preamplifiers feature internal dc-to-dc converters for highly stable operation from an external dc source. The preamplifiers are well protected by an input bandpass filter, an output circulator, and internal pulse width limiting. The preamplifier is housed in an EMI sealed package with forced air cooling built in.

The power module is a basic building block used in 86 locations in the transmitter, and is found in the preamplifiers, driver amplifier, and power amplifier. The power module (figure 5) provides 12 dB of gain with an output of 600 watts. The module utilizes 5 identical microwave transistors in a one driving four configuration, with 50-ohm input and outputs. The module is easily removed as a subassembly with its dedicated capacitor bank and quick disconnect RF connectors. The versatility of the power module is demonstrated by its application in various assemblies in the transmitter and its commonality contributes to a lower recurring cost through economy of scales.

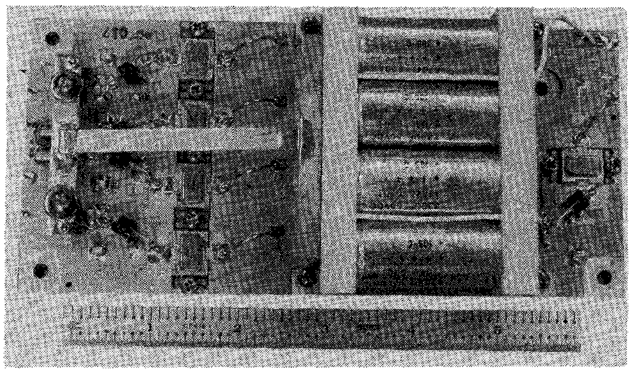


Figure 5

The driver stage of amplification is located in one of the four panel assemblies and is composed of RF amplifiers and a linear type dc regulator. The driver is capable of generating over 6 kW from its 12 identical power modules but is operated at a reduced bias level to produce only 3.0 kW. Operating the driver at reduced bias levels gives excellent reliability, and automatic level control circuitry can adjust the bias voltage to compensate for transistor failures in the driver stage. The level control circuitry monitors the driver stage output power by means of a proximity coupler, and adjusts the linear type dc regulator to the required bias levels. The regulator also serves to meet the stability requirements by maintaining precise pulse-to-pulse bias voltage control independent of any dc source variations. The 12 power modules are operated in parallel and their outputs are combined in isolated microstrip and air dielectric stripline combiners. The output transistors are protected against any erroneous VSWR conditions by internal circulators. The RF driver section is identical to half of a power amplifier panel.

The power amplifier stage consists of three identical power amplifier panels. Each panel contains 24 identical plug-in power modules and the necessary splitters and combiners for two equal inputs and two equal 6.0-kW minimum outputs. (Figure 6) shows one side of a panel con-

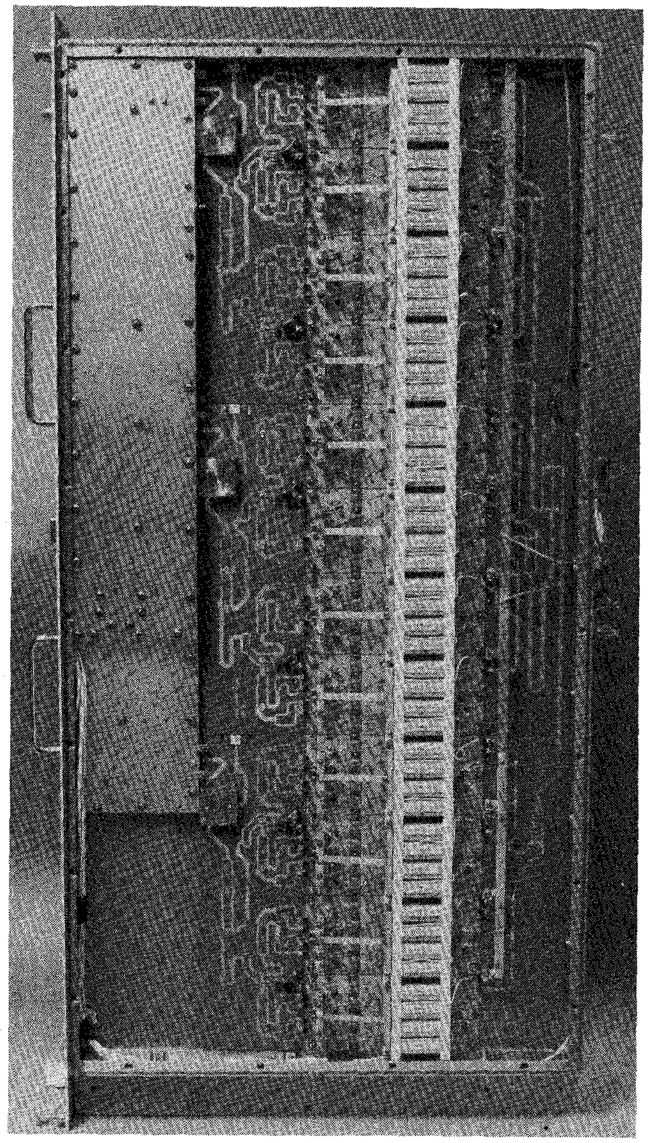
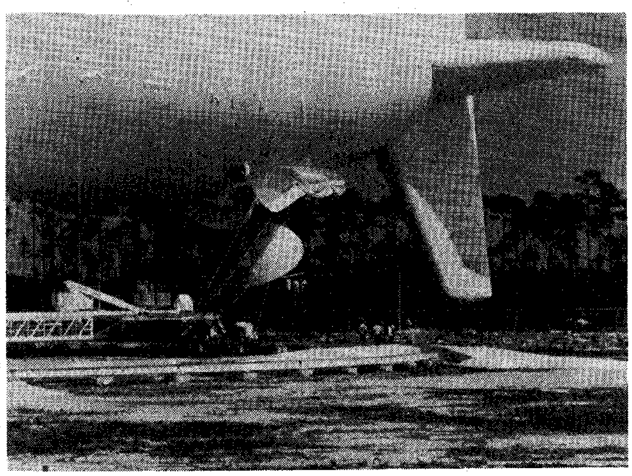


Figure 6

taining 12 power modules, while the other side is a mirror image with another 12 power modules. The panel construction uses a central air cooled coldplate to which the RF subassemblies are attached. Proximity couplers and detectors inside the panels allow for performance monitoring and fault diagnosis. The panels are completely enclosed for EMI shielding but are easily serviced because they are mounted on slides. Circulators protect the transistors from high output VSWRs, and temperature sensors on the panels are monitored to protect the transistors from cooling faults. The sensors are used to reduce the transmitter output power in the case of a partial cooling fault and shut down the transmitter for total cooling failure.

The six power supplies are high efficiency switcher type supplies designed specifically to recharge the storage capacitors in each power module during the interpulse period of operation. The supplies are a modified version of the well proven SPS-40 solid-state transmitter power supply, and provide very good pulse-to-pulse regulation even during staggered PRF formats. The power supplies have individual cooling fans with speed sensors, internal short circuit protection, and over-voltage shutdown circuitry. They are completely blind mating for quick maintenance, and operate at a nominal 40 Vdc, compared to the lethal kilovolts found in tube type transmitters. The preamplifiers and driver amplifier receive their dc power from a diode combination of the six supplies for a greater reliability than any one supply.



The control section of the transmitter provides several maintenance and performance monitoring functions. The transmitter is inhibited in the event of a blower failure, high panel temperature, excessive drive to power amplifier panels, high VSWR at output, or excessive PRF formats. Performance monitoring circuitry indicates output levels at the preamplifier, driver amplifier, each power amplifier, transmitter output power, and power supply voltage. Automatic circuitry controls the preamplifier switch-over function, as well as the control of the driver amplifier output power level. The control circuitry has been designed for easy expansion to minimize redesign for different output power configurations.

CONCLUSION

The use of L-band totally solid-state transmitters at peak power levels of 30 kW is now practical and have been deployed in operational systems. The LASS program for the U.S. Customs Service utilizes such a transmitter integrating a high degree of modularity, maintainability, and availability. The system also has a large amount of inherent redundancy which ensures meeting the system specifications while allowing individual transistor failures to occur. Built-in test, performance monitoring and calibration, and fault isolation capabilities are included in the transmitter design to ensure high availability and enhanced maintainability. The transmitter architecture is readily expandable to cover a variety of applications with a minimum of redesign.