A Satellite Data Terminal for Land Mobile Use

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ABSTRACT

Telesat Mobile Incorporated (TMI) has recently introduced the Mobile Data Service (MDS) into Canada. This paper outlines the system design and some key aspects of the detailed design of the Mobile Earth Terminal (MET) developed by Canadian Astronautics Limited (CAL) for use with the MDS. The technical requirements for the MET are outlined and the equipment architecture is described. The major design considerations for each functional module are then addressed. Environmental conditions unique to the land mobile service are highlighted, along with the measures taken to ensure satisfactory operation and survival of the MET. Finally, the probable direction of future developments is indicated.

REQUIREMENTS

The requirements for the MDS are to provide two-way digital messaging together with position reporting for long-haul vehicles and their associated dispatch centres. A central Hub facility provides communication between the dispatch centres and the satellite, and the METs communicate directly with the satellite. Protocols are an extension of Inmarsat's Standard 'C'[1] optimized for land mobile use. Message formats include pre-formatted, coded and free form text, each with two levels of priority, and broadcast messages in the outbound direction. Both scheduled and solicited position reports are provided. The Loran-C 100 KHz navigational system was selected for the positioning system in the initial version of the equipment.

Table 1 shows the primary performance requirements for the MET. In addition, there are stringent phase noise requirements, the need to reject strong adjacent signals, and a complex system of modulation and coding. These must be considered in the context of a low-cost terminal that will be constantly exposed to the rigours of the land mobile environment. Totally automatic operation and a simple user interface are dictated by the intended application.

ARCHITECTURE

The MET comprises three subsystems; Antenna, Transceiver and User Terminal. Figure 2 shows the block diagram of the arrangement adopted. The philosophy was to place in the transceiver all functions not located of necessity at either the antenna or the user terminal. This minimizes both the size and weight of the user terminal, and the replacement cost of the antenna.

Table I. Primary Performance Requirements for the MDS MET

Transmit frequency range:	1626.5 to 1660.5 MHz
Receive frequency range:	1530 to 1559 MHz
Channel spacing:	5 KHz
G/T:	-22 dB/°K min.
EIRP:	+15 dBW min.
Transmit duty cycle:	2.5%
Continuous transmission:	620 ms max.
Transmit/receive switching time:	<150 ms
Initial acquisition time:	5 minutes
Elevation coverage:	15° to 35°

Transceiver

The Transceiver contains the following components: up/down converter (Converter), baseband processor (BBP), Loran-C receiver, power amplifier (PA), and power supply (PS). The functions of each unit are as follows:

Converter. Provides reference frequency generation, frequency synthesis, down-conversion from L-band to baseband, upconversion of data input to BPSK L-band output, and separation of the received Loran-C signal.

BBP. Performs all digital processing, including unique-word (UW) detection, de-interleaving, demodulation, Viterbi decoding, descrambling, and the corresponding inverse operations. Also provides the satellite protocol processing and system control for the entire MET.

Loran-C Rx. Receives and demodulates 100 KHz Loran-C pulses, performs automatic selection of chains, measures time differences, compensates for propagation path characteristics, and computes latitude and longitude.

Power Amplifier. Class-C amplifier providing 35 W minimum output power over the full uplink band of 1626.5 to 1660.5 MHz. Also provides control bias for the transmit/receive (T/R) switch in the antenna subsystem.

Power Supply. Converts nominal 12 V vehicle power into +5 V, +15 V, and +28 V regulated supplies for the rest of the MET.

User Terminal

The user terminal was developed for CAL by Gandalf Technologies Incorporated. It has a full "Qwerty" keyboard with a numeric keypad, cursor control keys and four special function keys, a 40 character by four line liquid crystal display, two LEDs and an annunciator.

Antenna

The antenna uses a single element for both L-band communication and Loran-C reception. The single circuit board provides the following functions:

Low noise amplifier (LNA). Provides over 30 dB of low noise gain over the full receive band of 1530 to 1559 MHz.

Loran-C preamplifier. Provides gain and buffering for 100 KHz Loran-C signals

T/R switch. A pin diode switch to connect the antenna element to either the PA output or the LNA input.

Bias tee. Removes +15 V dc supply from coaxial cable for use in antenna subsystem.

Diplexers. Separate and combine L-band and Loran-C signals.

DESIGN DETAILS

Converter

The converter presented a difficult design challenge. The combination of high frequency, close channel spacing and low phase noise led to the adoption of a three loop configuration for the main synthesizer (LO1) with a fourth loop for the second local oscillator (LO2). The crystal reference oscillator operates at 8 MHz, and an AFC loop performs fine tuning by using the outbound TDM signal from the satellite as a frequency reference. Downconversion is performed in three stages; first to 70 MHz, then to 4 MHz, and finally to a pair of quadrature baseband channels. Two ten bit A/D converters digitize the baseband signals for further processing by the BBP. No upconversion takes place as such. The main synthesizer generates the required L-band frequency directly, and this is then BPSK modulated and fed to the PA.

Baseband Processor

The BBP uses two processors; a TMS320C25 for digital signal processing, and a 16 bit μP for control and satellite protocol functions. A large programmable logic device is used to implement the necessary logic functions, and several serial interfaces are provided. The internal interfaces are for control of the synthesizer, reference oscillator, T/R switch and PA, and data input from the A/D converters and Loran-C receiver. The external interfaces are for the User Terminal and an Auxiliary Port. A test port is also provided.

Loran-C Receiver

The receiver selected is a board-level product intended for land mobile applications. It includes automatically tunable notch filters for interference rejection and provides completely automatic operation.

Power Amplifier

The PA has five silicon bipolar stages; two linear and three grounded base class 'C'. Only the linear stages are keyed since the class 'C' stages draw no current until they are driven. As stated earlier, the PA is located in the transceiver, which results in about 2 dB of loss in the antenna cable and leads to a requirement for a nominal 40 W output from the PA. The output stage uses a pair of devices combined in quadrature since no suitable single device was available at the time of device selection. The greatest challenge in developing this module has been to ensure unconditional stability over the full temperature range. This has been achieved by a combination of careful layout, extensive decoupling and the use of lossy ferrite beads on bias lines.

Power Supply

The power supply operates at 70 KHz to avoid interference with the Loran-C receiver. It is designed to accommodate the zero to full load transient on the 28 V output imposed by keying the PA. Excellent cross-regulation is critical to avoid frequency chirp on the transmitted burst. Linear regulators are used on two of the outputs to meet this requirement.

User Terminal

The user terminal has a rubber membrane keypad and a "supertwist" LCD display housed in a small, robust injection-moulded enclosure. Internally, a microprocessor with associated RAM and EPROM, a serial I/O interface and a power supply provide the required functionality. A single cable provides both power and a two-way data path from the Transceiver to the User Terminal.

The software uses a simple menu-driven system for selecting and editing messages, which can also be stored for future recall.

Antenna

Figure 1 shows a cross-section of the antenna, which presented one of the most interesting challenges of the whole development program. A gain of +2 dB was required to meet the G/T specification, and an omnidirectional configuration was specified to avoid the difficulties of beam steering. After a number of attempts, a quadfilar helix with a circular ground plane was adopted. Even with the specified gain, the losses in the T/R switch dictated the use of a GaAs FET first stage in the LNA, followed by two bipolar stages. A bandpass filter between the first and second stages protects the LNA from overloading in the presence of an adjacent transmission from another MET. The antenna ground plane is provided by the circuit board, whose active components are mounted on the underside.

The helix functions also as an electrically short monopole for reception of vertically-polarized signals at 100 KHz. The output from the Loran-C preamplifier is combined with the L-band output from the LNA in a diplexer and fed to the transceiver down the receive coaxial cable.

The T/R switch is implemented with a series/shunt PIN diode combination, and control bias is fed from the PA via the transmit coaxial cable.

ENVIRONMENTAL CONSIDERATIONS

The primary application for the MET is in long-haul trucks, and the implications for the design of the equipment must be given serious consideration. Some of the documented[2] physical stresses in these vehicles include 20 g shocks, vibration up to 4 g over 10 Hz to 1 KHz, wide temperature and humidity extremes, temperature shock and cycling, and exposure to oil and chemicals. In addition, the antenna may be exposed to wind loading, solar radiation, precipitation, salt fog, blowing sand and dust, small flying rocks, rotating brushes, high pressure hoses, and the occasional tree branch. A heavy aluminum extrusion has been selected for the transceiver housing, and this in turn is installed in a shock-mounted tray. The antenna uses rugged polycarbonate mouldings with a clamped O-ring seal. Careful design and selection of materials combined with extensive environmental testing has led to a design which is considered likely to give good service for many years.

Electrical stresses arise from equipment connected to the vehicle supply, and can include transients up to 600 V for 1 ms, and occasionally 150 V for 400 ms. Clearly a power supply designed for a nominal 12 V input needs careful protection to survive such treatment. A combination of fusing, filtering, and transient absorption devices has been adopted to ensure uninterrupted operation during the shorter transients and survival of the longer variety.

FUTURE PRODUCT EVOLUTION

Two trends are clearly apparent in considering the future of the MET as an evolving product:

Cost Reduction

A constant downward pressure on prices exists. This will be met by measures such as a higher level of integration, and the arrival of new devices for frequency synthesis, power amplification, and digital processing. Increased capital investment will also be required to optimize tooling, streamline the production flow, and improve test facilities.

Inter-operability

Future generations of mobile terminal will be expected to operate not only with the Canadian MDS system, but also with AMSC, Inmarsat's Standard 'C', and MSAT.

REFERENCES

1. **INMARSAT**, Standard-C, System Definition Manual, Release 1.3, July 1989.

2. **SAE** 1988. Joint SAE/TMC Recommended Environmental Practices for Electronic Equipment Design (Heavy-Duty Trucks) SAE J1455. Society of Automotive Engineers, Inc.

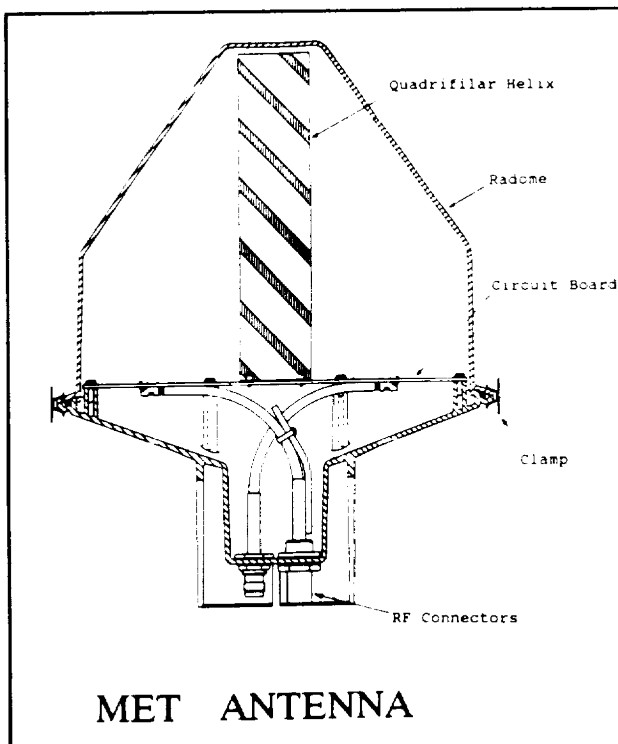

Figure 1. Cross-sectional view of MET Antenna

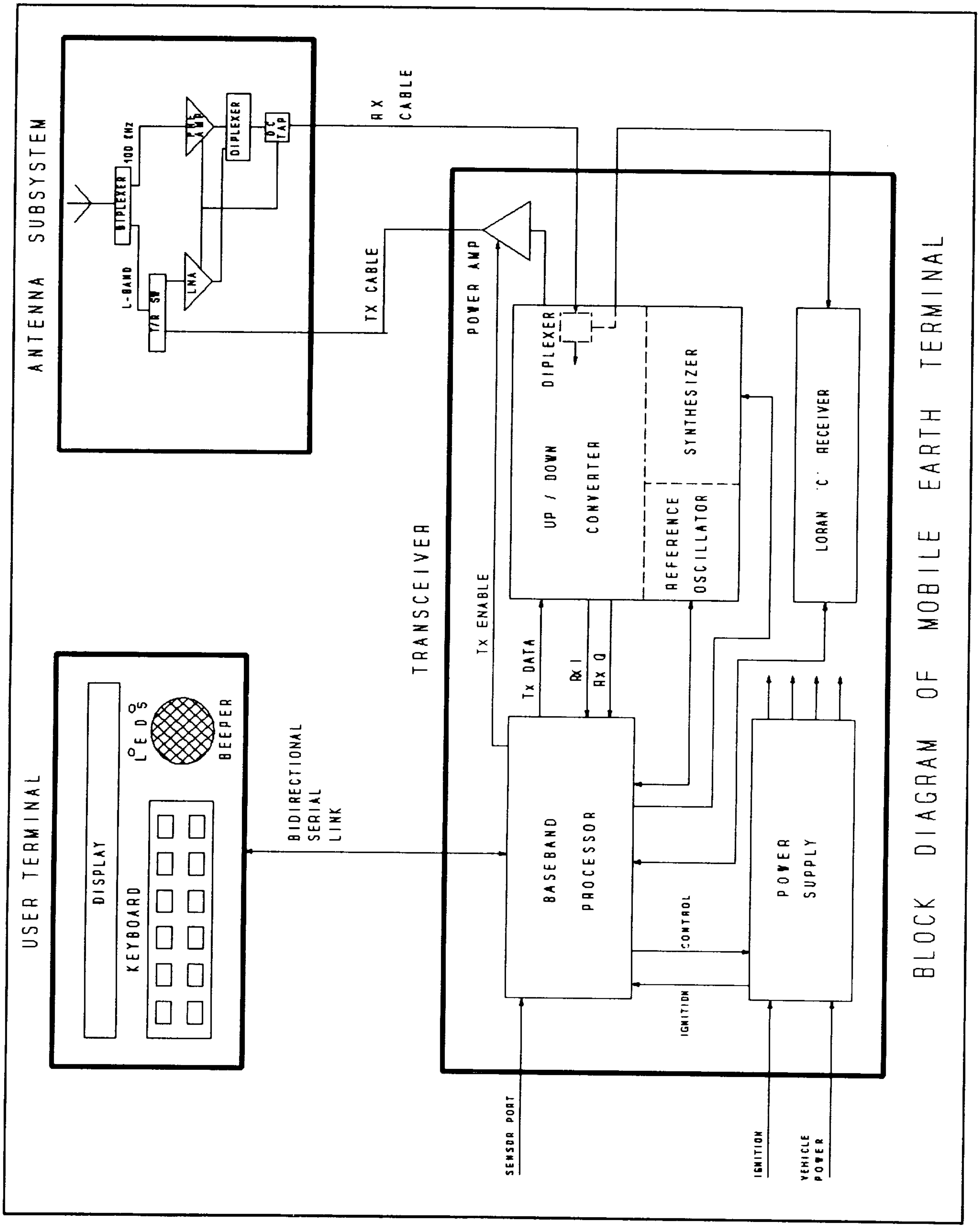

Figure 2. Block Diagram of the MDS MET