TECHNICAL CHARACTERISTICS OF THE OMNITRACS - THE FIRST OPERATIONAL MOBILE KU-BAND SATELLITE COMMUNICATIONS SYSTEM

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ABSTRACT

The technical characteristics of the OmniTRACS system are described. This system is the first operational mobile Ku-Band satellite communications system and provides two-way message and position determination service to Mobile Terminals using existing Ku-Band satellites. Interference to and from the system is minimized by the use of spread spectrum techniques, together with low power, low data rate transmissions.

INTRODUCTION

The OmniTRACS Network (developed for Omninet Corporation, Los Angeles, CA) provides Mobile users with a cost-effective, two-way message and position location service using existing Ku-Band satellites. An optional position-determination device integrated into the Mobile terminal allows the position to be transmitted automatically to the Hub. A variety of preformatted and free-form text messages of up to 2000 characters are supported. An optional printer will permit transcription of messages to hardcopy.

Figure 1 shows the basic OmniTRACS system. All message traffic passes through a central Hub or Network Management Facility (NMF). The NMF contains a 7.6 meter earth station including satellite modems for communication with the Mobile terminals via the satellite, a Network Management Computer for message management and tracking, and telephone modems for connection with customer operation centers.

Because transmission from a mobile platform at Ku-Band falls under a secondary allocation, the units must not interfere with fixed services but at the same time must tolerate interference from those services. This calls for a design approach akin to an LPI anti-jam system. Accordingly, a judicious combination of frequency hopping and direct sequence spread spectrum waveforms are utilized, together with low power, low data rate transmissions.

The OmniTRACS system began operational tests in January, 1988 in which a Mobile terminal was driven from coast to coast in constant communication with a Hub terminal located in San Diego, California. Operation was very successful in all kinds of environments from wide open Western freeways to the concrete canyons of New York City. The program is now entering production.

SYSTEM DESCRIPTION

The system uses two transponders in a single Ku-Band Satellite. One transponder is used for a moderate rate (5 kbs) continuous data stream from the Hub to all the Mobile

Terminals (system users can also be transportable or fixed) in the system. Messages are addressed to individual Mobile terminals or to groups of Mobile terminals on this channel. To aid in frequency co-ordination, two forward link modulations are provided. In one, frequency-hop spread-spectrum techniques are used to spread the power density over a wide bandwidth. These techniques reduce the downlink power density to acceptable levels and provide processing gain that the Mobile Terminals use to reject the signals from adjacent satellites. The other modulation for the forward link uses a triangle wave FM dispersal waveform similar to that used by satellite television signals, resulting in interference properties similar to television signals.
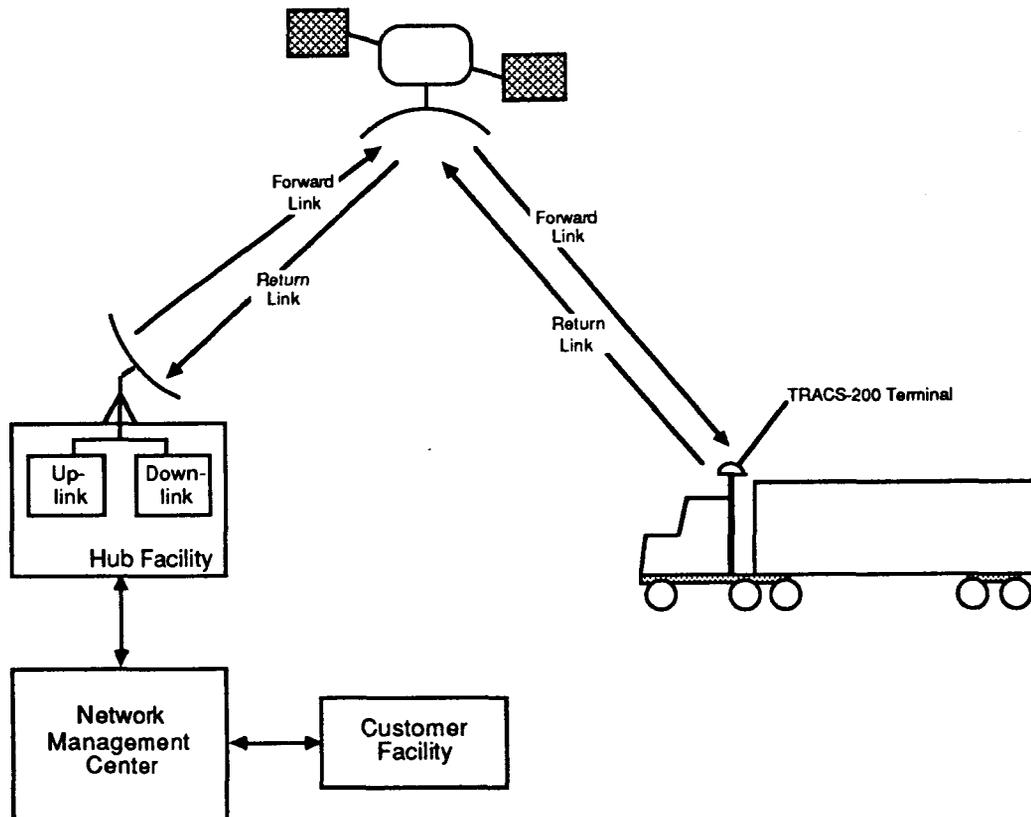
Figure 1: OmniTRACS System Block Diagram

A second transponder on the same satellite is used by the return link. Each Mobile terminal has a low transmit power level (+19 dBW EIRP). This power level allows data rates on the return link ranging from 22 to 132 bps, depending on available link margin for each individual terminal. The antenna pattern of the mobile terminal is rather broad (~6° beamwidth along the orbital arc) and therefore the potential exists—even at such low power levels—to cause interference to users in adjacent satellites. To mitigate this interference, several techniques are used:

1. Direct-sequence spread-spectrum techniques are used to spread the instantaneous power spectral density of each mobile uplink over a bandwidth of 1.0 megahertz.

2. Frequency hopping and FDM techniques are used to ensure that the power spectral density produced by the combination of all active Mobile Terminals is uniformly spread over a bandwidth of 48 megahertz.

3. The transmissions of the mobile terminals are very carefully controlled. A mobile terminal will not transmit unless commanded to do so, either as a direct request

(acknowledgement, report, etc.) or as a response to a carefully defined—and limited—group poll. This polling technique controls the number and frequency location of mobile transmitters at all times so that the level of interference can be tightly regulated. Furthermore, reception of the command implies that the antenna is correctly oriented for transmission.

As a result of the above techniques, interference to other satellite services by a network consisting of tens of thousands of Mobile terminals is less than that caused by conventional VSAT terminals.

MOBILE TERMINAL DESCRIPTION

Figure 2 shows a functional block diagram of the mobile terminal. A microprocessor implements all of the signal processing, acquisition and demodulation functions. The antenna has an asymmetric pattern (~40° 3 dB beamwidth in elevation and ~6° beamwidth in azimuth). It is steerable in azimuth only. A low-noise amplifier and conventional down-conversion chain provide a signal to the microprocessor for acquisition, tracking and demodulation. During transmission, an up-conversion and spreading chain provide signal in the 14-14.5 GHz band to the 1.0 Watt power amplifier. This signal is transmitted via the steerable antenna that has a maximum gain of +19 dBi for a total transmit power of +19 dBW.
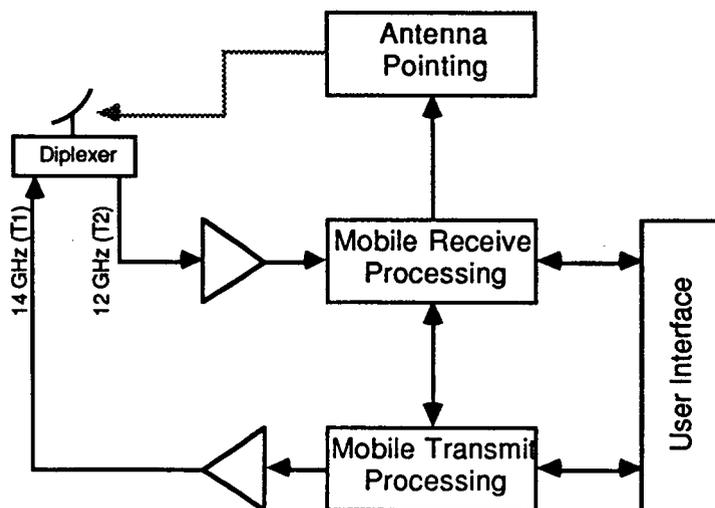

Figure 2: Mobile Terminal Block Diagram

Whenever the Mobile unit is not in receive synchronization, it executes a receive acquisition algorithm until data from the satellite can be demodulated. At this point, the antenna is pointed towards the satellite and messages can be received from the Hub. When commanded by the Hub, the Mobile may start transmission of a message. The terminal is half-duplex, and transmissions are done at a 50% duty cycle to allow for continued antenna tracking of the received downlink signal. If at any time during a transmission the receive signal is lost, the terminal ceases transmission to prevent interference from being generated.

DESCRIPTION OF RETURN LINK MODULATING SIGNAL

Binary data at 44.1 bits per second is rate 1/3 convolutionally encoded to produce code symbols at a rate of 132.3 symbols per second. These code symbols are used four at a time to drive a 16-ary FSK modulator at a rate of 33.1 FSK baud. A 50% transmit duty cycle produces an FSK symbol period of 15.1 ms. The tones out of the FSK modulator

are direct-sequence spread at a rate of 1.0 Megachip per second for an instantaneous bandwidth of 1.0 MHz. This 1.0 MHz bandwidth signal is then frequency hopped over a 48 MHz bandwidth. To maximize system capacity in areas with good satellite G/T and to provide adequate margin in areas with poor G/T, 0.5x and 3.0x data rates of 22.0 and 132.3 bps are also provided. These are implemented by FSK symbol repetition and a three times FSK symbol rate respectively.

RETURN LINK POWER DENSITY

The OmniTRACS Terminals meet the VSAT Inbound Guidelines for transmit power density along the equatorial arc. Figure 3 shows the Mobile Terminal antenna pattern in azimuth keeping elevation at maximum gain. This figure assumes a nominal boresight gain of 19 dBi. The sidelobes of this antenna are asymmetric and non-uniform, but stay below -12.0 dB relative to boresight gain.
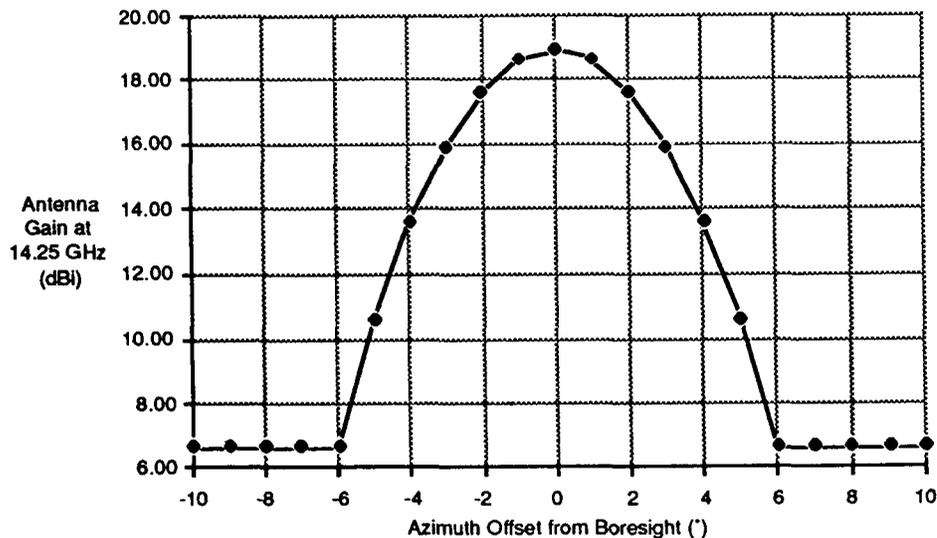

Figure 3: OmniTRACS Transmit Antenna Gain (Azimuth Cut)

Table 1 shows the maximum transmit power density link budget for the OmniTRACS System Return Link with 250 units transmitting simultaneously. Table 1 combined with the OmniTRACS transmit antenna pattern of figure 3 produces the EIRP power density shown in figure 4. Also shown in figure 4 is the guideline from footnote 35 of the April 9, 1986 Declaratory Order.

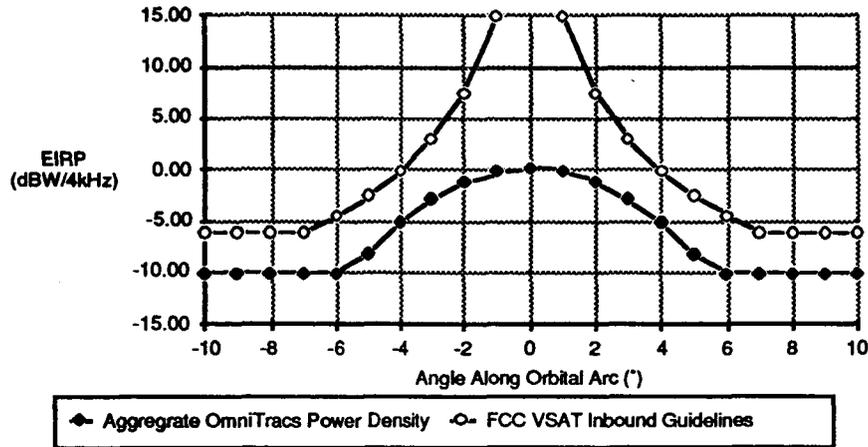| Table 1: OmniTRACS System Return Link Power Density		
Max. Tx Power	1.26 Watt	1.0 dBW
Max. Tx Antenna Gain		19.0 dBi
Occupied BW	48,000,000 Hz	-76.8 dB/Hz
FCC Reference BW	4,000 Hz	36.0 dB-Hz/4kHz
Number of Uplinks	250	24.0 dB
Tx Duty Cycle	50%	-3.0 dB
System EIRP Density		0.2 dBW/4kHz

Figure 4: OmniTRACS Return Link Power Density Compared to FCC VSAT Inbound Guideline

DESCRIPTION OF FORWARD LINK MODULATING SIGNAL

Binary data at 4,960.3 bits per second is rate 1/2 block encoded to produce code symbols at a rate of 9,920.6 symbols per second. These code symbols are used to drive a BPSK modulator at a rate of 9,920.6 PSK baud. In mode A, this signal is frequency hopped to a new center frequency every 5.04 ms to occupy a total bandwidth of 24 MHz.

Mode B uses a triangle wave dispersal waveform instead of frequency hopping, resulting in similar co-ordination properties to video signals. The Mode B power density calculations are shown below in table 2.

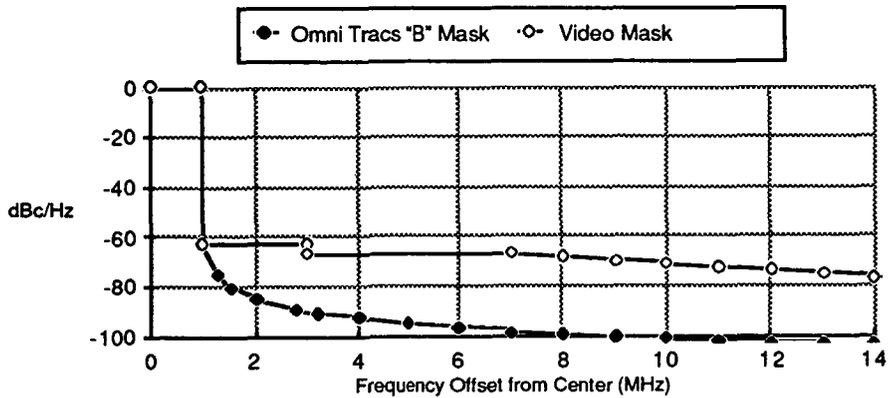| Table 2: Mode B Forward Link Power Density		
Satellite Transmit EIRP		44.0 dBW
Occupied Bandwidth	2,000,000 Hz	-63.0 dB/Hz
Reference FCC Bandwidth	4,000 Hz	36.0 dB-Hz/4kHz
Transmit Power Density		17.0 dBW/4kHz

Figure 5: Suggested Coordination Mask for OmniTRACS Mode B Forward Link Compared with Video Coordination Mask

Coordination for Mode B will be easier than coordination of a video signal. The frequency band in the range of ±1.0 MHz about the center of the dispersal waveform will contain relatively high instantaneous power densities, but the frequency bands outside of this ±1.0 MHz range will drop off rapidly—even faster than video signals. Figure 5 shows the coordination mask that should be used with the OmniTRACS Mode B Forward Link Signal compared with the coordination mask suggested by the FCC Advisory Committee on 2° Orbital Spacing for video signals.

DESCRIPTION OF MOBILE TERMINAL HARDWARE

The OmniTRACS Mobile Terminal, shown below in Figure 6, consists of three units: the Outdoor Unit, the Communication Unit and the Display Unit. The OmniTRACS terminal can operate in a temperature range between -30° and 70°C.

The Outdoor Unit contains the antenna assembly and front-end electronics. The outdoor unit (including antenna) is approximately 10" in diameter, 6" high and weighs approximately 9 lbs. The Outdoor Unit can be mounted on a vehicle roof or a mast (for a truck cab).

The Communication Unit contains an analog section, digital electronics and the LORAN receiver which are contained on four circuit card assemblies. The approximate dimensions of the Communication Unit are 4"x8"x9" and it can be mounted anywhere in the vehicle since it does not require operator access.

The Display Unit consists of a 40 character by four line display and an ABCD or QWERTY keyboard. The display unit also provides several function keys for pre-programmed user functions. The display contains indicators for message waiting, satellite synchronization and power indication. The display unit also provides a maintenance mode for in-field troubleshooting and Mobile unit initialization. The display unit is 6"x10"x1" and can be located on the dashboard or any other convenient location.

Figure 6: Mobile Terminal Hardware