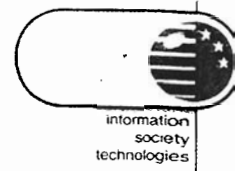


# Proceedings

**IST MOBILE COMMUNICATIONS SUMMIT 2001**



**EXPANDING THE WIRELESS UNIVERSE**

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## Proceedings

**Barcelona, Spain 9-12 September 2001**

**Hotel Meliá Gran Sitges**





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# **Proceedings**

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The Information society Technologies Programme (IST) is a major theme of research and technological development within the European Union's Fifth RTD Framework Programme, (1998-2002). IST is conceived and implemented as a single and integrated programme that reflects the convergence of information processing, communications and media technologies.

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# SUITED Vehicular Ka Band Satellite Terminal

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*The paper presents the approach taken for the design of the GMBS Mobile Multimode Terminal within the SUITED project. The phase-antenna concept developed for the demonstrator activity is presented.*

## I. Introduction

In the SUITED project the definition and the design of the GMBS Mobile Multimode Terminal (GMMT) constitutes one of the main challenges of the project. In it the satellite access sub-system is the most innovative part of the terminal. Figure 1 shows the general diagram of the satellite sub-system of the GMMT.

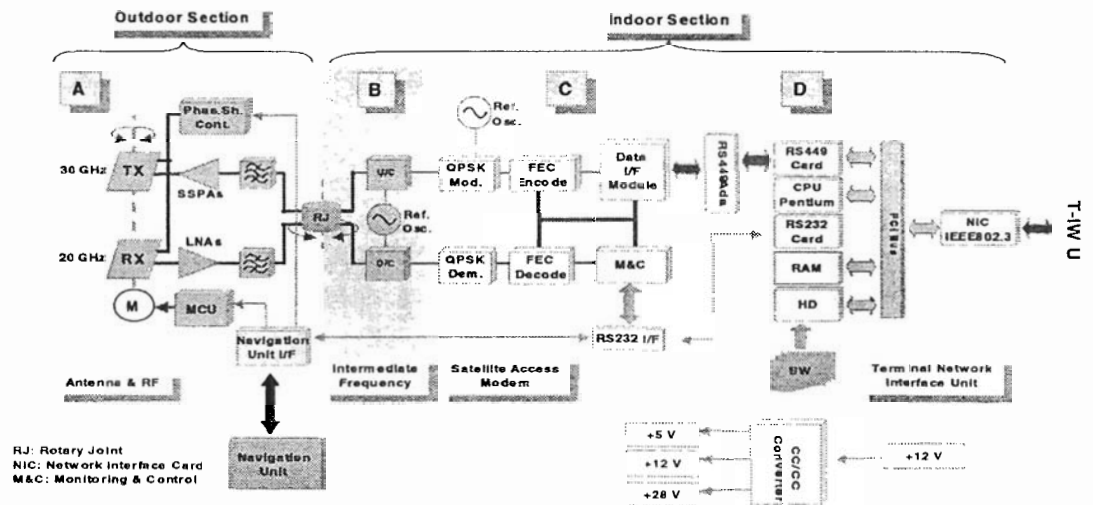


Figure 1: GMMT satellite terminal diagram

The satellite terminal is composed of four main parts: the RX and TX phased array antenna, the RF and IF section comprising the modem, the EuroSkyWay (ESW) Network Interface Unit (NIU) and the navigation unit. The IF and modem sections are constitute by off-the-shelf products and they are not discussed in the present paper.

## II. Antenna Design Concept

### II.1 Antenna System

The satellite antenna of SUITED demonstrator is designed to link ITALSAT, an Italian geostationary satellite operating in transparent mode on Ka band.

The antenna is intended to be mounted on the roof of the car. Thus, for esthetical and

implementation reasons, minimal antenna height has been one of main design challenges. Antenna beam agility of the high gain antenna is realised in an hybrid way: mechanically in the azimuth plane ( $360^\circ$ ) and electronically in the elevation plane. The expected elevation range is  $40 \pm 8^\circ$ .

Taking into account the previous considerations, an active phased-array antenna has been designed separating it into two parts, transmitting antenna and receiving antenna, in such a way that the feeding network is simpler. The radiating elements used are microstrip printed anti-resonant dipoles working near the second resonance and printed in cuflon substrate  $\epsilon_r=2.1$  and  $h=0.508\text{mm}$ . The advantages of these dipoles is, that they have impedances of several hundreds Ohms magnitude, and that is the reason why they are convenient for parallel connection in antenna arrays.

This kind of dipoles are formed by printing one arm of the dipole on one side of the substrate and the other arm in its opposite side and backed by a metallic ground plane at a distance of a quarter of wavelength in order to increase the gain of the antenna and to produce radiation only in one direction. It is in this way that the vertical linear signal polarisation is achieved.

To avoid large scan losses, because of the very small elevation angle, the antennas are inclined at a certain angle. To make height of antenna smaller each antenna, transmitting and receiving, are also divided into inclined sub arrays. Figure 2 shows the concept of design although afterwards it will be explained which is the exact number of elements that make up each sub-array.

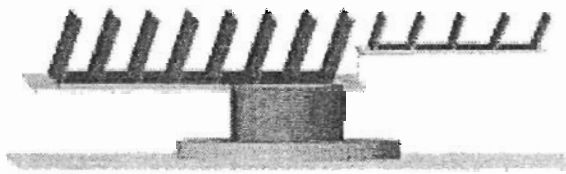


Figure 2: Concept of Ka-band antenna

With this concept it is achieved the same effect that having one only panel inclined the suitable angle to point to the right direction but with the advantage that the height is considerably reduced.

According to the requirements of antenna gain, beam scanning and available space constraints, the needed features of the car ODU antennas can be obtained with 8 arrays of 32 elements for the TX antenna and 12 arrays of 32 elements for the RX one. This number of elements guarantees that the gain of the RX antenna is 31.5 dB and the gain of the TX antenna is 29.3 dB. In order to achieve the pointing to the lower elevation angle a phase shift of  $45^\circ$  between the different rows that constitute the antenna must be applied.

## II.II. Antenna pointing, acquisition and tracking (PAT) for land mobile vehicles

Because of the small antenna beamwidth the SUITED Demonstrator antenna requires a precise PAT process to steer the antenna exactly towards the satellite direction in order to establish a communication link. A definition of the term PAT for mobile satellite communication, a basic overview on PAT algorithms and agility requirement for land mobile terminal antennas are given in [HLO00].

Basis for a specification of an optimal mobile antenna system is the knowledge of the antenna beam agility requirements. On the one hand this is input for the core antenna design and on the other hand a cost-efficient solution for the problem PAT also, requires this information about the maximum angular range, rate and acceleration in azimuth and elevation encountered for the mobile's antenna. These values differ significantly for the various mobile communication scenarios.

In a land mobile scenario the vehicle movements are highly dynamic and angular change rates become a dominating factor for antenna beam agility design. Thus, not only information about the maximum angular range were required, but also rate and acceleration in azimuth and elevation encountered for the mobile's antenna were investigated for optimal antenna and PAT design. Moreover, aerodynamics, aesthetics and low cost realisation pose another

challenge. Table 1 shows the resulting angular range, rates and accelerations for the SUITED demonstration, based on geometric considerations, a measurement campaign and simulations [HLO00]. While the given rate and acceleration values chosen to be valid for all land mobile scenarios, the elevation range of the antenna has to be enlarged for the EuroSkyWay target system, due to the expanded service area of the satellite and the increased operational area of the terminal, respectively.

	elevation	azimuth
range	30 ° to 47 °	360 °
rate	20 °/sec	40 °/sec
acceleration	100 °/sec <sup>2</sup>	50 °/sec <sup>2</sup>

Table 1. Angular range, rates and acceleration in elevation and azimuth.

The land mobile satellite channel at Ka band is suffering from intense shadowing [JH98], this brings about an important influence on the steering algorithms.

PAT methods relying on information derived from the received signal strength (closed loop) are influenced in performance by shadowing. Moreover, those algorithms require mostly either multiple antenna lobes or any kind of main lobe dithering. Multiple beams require additional receiver effort, dithering may reduce lifetime of a mechanically steered system.

Open loop PAT algorithms operate completely independent from channel characteristics. Hereby the antenna's azimuth and elevation are calculated by the knowledge of the fixed (GEO) satellite position and the mobile's position and attitude. The position of the mobile can easily and sufficiently precise determined by available navigation systems (GPS). Assuming a vehicle to be equipped with a high sophisticated communication system, also supported by navigation and travel information, a navigation unit becomes anyway indispensable. Moreover, this functionality will enhance the system capabilities manifold. Unfortunately a car is a highly dynamic attitude changing vehicle, so angular change rates become the dominating factor for the antenna hardware and antenna PAT. This requires additional sensors for the mobile's attitude information.

Keeping in mind the agility of the antenna - mechanical in azimuth and electronical in elevation, the PAT algorithm for the SUITED demonstration will be realised with open loop focus. Based on the information already available in a commercial car navigation unit (one axis gyro, speed, GPS), in some way modified and optimised for fast heading the antenna will be controlled in azimuth. This information will be enhanced by signal feedback o compensate gyro drifts and maintain elevation pointing.

### II.III RF front-end

Another important aspect in the design of the car terminal is the RF circuitry. The transmitter RF chain operates at 29.75 GHz and the receiver one works at 19.75 GHz with a bandwidth of 500 MHz. The architecture of the RX RF chain comprises low noise amplification, phase shifting and power combination and the architecture of the TX RF chain comprises power amplification, phase shifting and power combination.

The phase shifters are a critical point in the whole structure due to the fact that they are used to point the main beam in elevation at the right position. This elevation steering is made by means of analogue phase shifters obtaining in this way a continual phase changing. A phase shift of 45° degrees between sub-arrays is needed for the pointing of the antenna to the lower elevation angle, that is 32°. This phase shift is changeable up to 110° in order that the achieved pointing elevation angle is 48°. The antenna has been designed in such a way that not grating lobes, or grating lobes with a level under -13 dB, appear in all the scan angles.

The phase shifters are designed using branch couplers for the RX antenna and rat races for the TX one. By controlling the voltage of the diodes connected at the branches of the couplers a variable phase shift enough to move the radiation pattern in elevation is achieved.

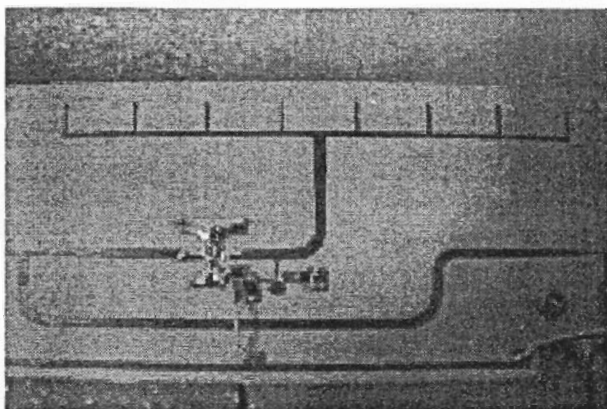


Figure 3: LNA integrated with one RX sub-array

To implement the concept of active antenna, the Low Noise Amplifiers are located near the RX radiating elements and the Power Amplifiers are placed near the TX radiating elements. In any case, one amplifier is allocated per sub-array. Figure 3 shows the LNA integrated with one RX sub-array of dipoles.

Taking into account the features of the amplifiers used in the terminal the achieved EIRP is 37.3 dBW and the G/T is 6 dB/K.

All the RF front-end is implemented in microstrip technology. The phase shifters and power combiners are located on the surface of the platform that supports the whole structure of the antenna. The link between the TX and RX antenna is made by means of a diplexer which carries the signal to/from the corresponding antenna to the rotary joint. It is through it that the RF signal passes.

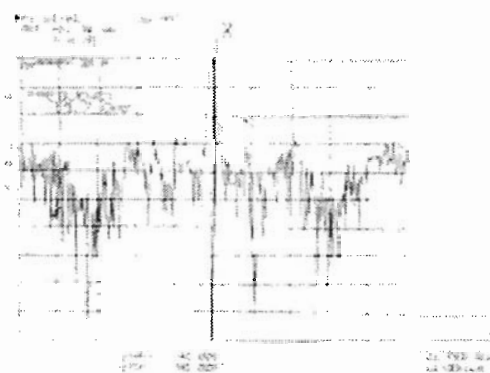


Figure 4a: RX antenna. H plain pattern (azimuth plane)



Figure 4b: RX antenna. E plain pattern (elevation plane)

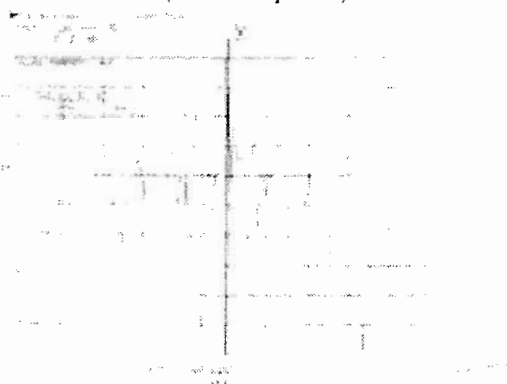


Figure 4c: TX antenna. H plain pattern (azimuth plane)

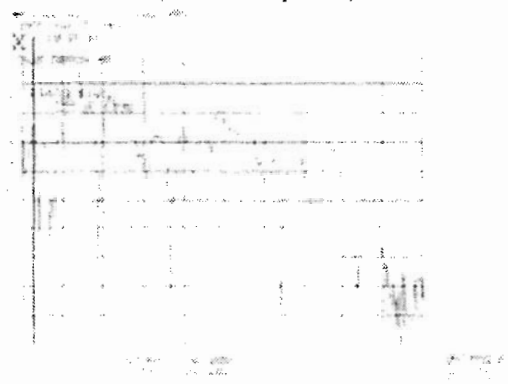


Figure 4d: TX antenna. E plain pattern (elevation plane)

The motor of the mechanical subsystem is hidden below the antenna holder. The transmission of movement in azimuth is made using right bearings. The motor is located in vertical position.



Finally, the results of some measurements are presented. Figures 4 (a, b, c and d) show the results of measurements for the RX and TX antenna in azimuth and elevation planes for the lower position. It can be seen that the level of grating lobes is under  $-13$  dB. The x-axis represents an axis perpendicular to the planes in which dipoles are located.

#### II.IV. The Terminal Network Interface Unit

The T-NIU constitutes the interface between the T-IWU and the ESW satellite network, for this reason it acts as a gateway to connect the IP network side with the EuroSkyWay (ESW) protocol environment. Three main functions are the objectives of this sub-system: the fragmentation and de-fragmentation of the IP packets to host them on the ESW cells (encapsulation procedure), the signalling exchange with the ESW payload core, the probing of the satellite signal level using the modem capabilities.

Receiving an IP datagram from the user network (from the Terminal-InterWorking Unit), the T-NIU starts the fragmentation and encapsulates it on the ESW cells, on the other way it reads the ESW cells and de-fragments data to re-build the IP packets. Also the T-NIU manages the ESW signalling by means the Traffic Resource Manager (TRM) and the Network Control Centre (NCC).

During this operation, the T-NIU guaranties a complete transparency between the IP access and the ESW environment. Also the T-NIU provides to read the modem parameters about the satellite field capability status and encapsulates this information in the IP packets flowing towards the T-IWU.

Physically the T-NIU is based on an off-the-shelf PC board where a custom software runs. For the SUITED demonstrator, a PC/104 standard PC board constitutes the T-NIU where suitable software manages and performs all the inter-working operations between the T-IWU and the ESW satellite access. A 10BaseT interface based on an Ethernet Network Interface Card (NIC) links the T-IWU and a RS422/485 serial card, supporting rate up to 1 Mbps on the satellite access modem. From the modem, using an RS232C serial interface, the T-NIU receives all the link information ( $E_b/N_0$  and BER).

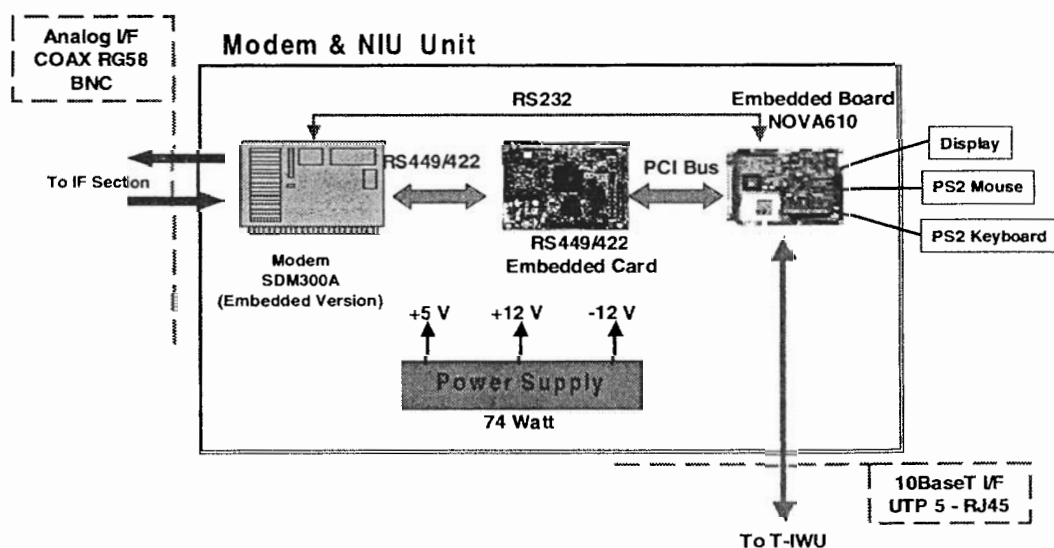


Figure 5: T-NIU and SAT modem configuration layout

Figure 5 depicts the general layout of the T-NIU and the modem.

In the T-NIU there are some threads running simultaneously to manage the access to the LAN, the access to the serial port and the ESW protocol.

A satellite path information module uses the RS 232 serial interface to communicate with the

modem to ask periodically the information about the status of the satellite link. This module processes this data and builds the messages to send to the T-IWU to inform it about the link availability. These messages are passed to the LAN module that sends them to the T-IWU using UDP/IP datagrams. In this way the link information are passed to the T-IWU using the same data flow and channel exchanged between the two entities (T-IWU and T-NIU), the discrimination is performed addressing the ancillary data on different logical port well known by the T-IWU.

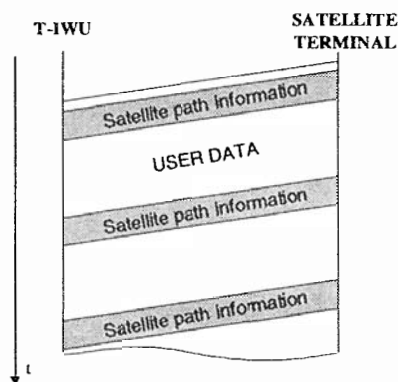


Figure 6: User data and information flows

The LAN access block reads the data directly from the MAC layer, so it can read also the datagrams with destination address different by the satellite IP address. When user data are read, the LAN access module passes the datagrams to the ESW protocol handling module that analyses the packets and sends them to the satellite using the ESW protocol.

When the connection is established the Fragmentation and Header Insertion procedure is executed on

every datagram to build the ESW cell sent through the ESW network.

When ESW cell are received, the T-NIU rebuilds the IP datagram and send it to the T-IWU that reply sending the packet to the user.

### III Conclusion

The satellite access sub-system of the GMBS Mobile Multimedia Terminal (GMMT) has been presented giving a special attention to the kind of antenna used for the demonstrator activity of the SUITED project. Also the T-NIU represent another critical elements to make available the access to the ESW satellite network that represents the core access network in the SUITED wireless environments. To drive the necessary tracking procedures, an appropriate navigation system has been integrated, managed by a suitable pointing algorithm. The complete set-up of the satellite access system, constitutes one of the main technological component in the SUITED activity.

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