FODA/IBEA-TDMA
SATELLITE ACCESS SCHEME FOR MIXED TRAFFIC AT VARIABLE BIT AND CODING RATES.
SYSTEM DESCRIPTION

Technical CNUCE Report C92-05

April 1992

Nedo Celandroni
Erina Ferro
Vlado Mihal
Francesco Potorti

FODA/IBEA-TDMA

Satellite access scheme for mixed traffic at variable bit and coding rates.

System description

Nedo Celandroni (CNUCE -CNR)
Erina Ferro (CNUCE - CNR)
Vlado Mihal (Visiting Professor - ENERGOINVEST - YU)
Francesco Potortì (Scholarship-holder of Telespazio S.p.A.)

CNUCE - Institute of National Research Council
Via S. Maria 36 - 56126 Pisa (Italy)

Tel.: +39-50-593312/593207/593203
Fax: +39-50-589354
Telex: 500371 CNUCE
E-mail: nedo@icnucevm
erina@icnucevm

CNUCE REPORT C92-05
April 1992

Work carried out in the framework of the Italian experimentation program with the Olympus satellite, co-ordinated and funded by ASST (Azienda di Stato Servizi Telefonici)/ISPT (Istituto Superiore PT).

ACKNOWLEDGEMENTS

The authors wish to thank Telespazio S.p.A. and in particular Mr. A. Marzoli and Mr. M. Neri for their precious collaboration.

TABLE OF CONTENTS

GEC-MARCONI TECHBRIEF

SUMMARY

This report describes the FODA system working at variable coding and bit rates (*FODA/IBEA-TDMA).*
FODA/IBEA is the natural evolution of the FODA-TDMA satellite access scheme working at 2 Mbit/s fixed rate with data 1/2 coded or uncoded. FODA-TDMA was used in the European SATINE-II experiment [8].
We remind here that the term ***FODA/IBEA system*** is comprehensive of the FODA/IBEA-TDMA (1) satellite access scheme and of the hardware prototype realised by the Marconi R.C. (U.K.). Both of them come from the experience of the fixed rate phase, but they have been completely re-designed to work at variable coding and bit rates to cope with the fade of the signal due to bad atmospheric conditions when the system is working at frequencies above 10 GHz.
In addition, up-link power control can also be operated from stations having sufficient power margin, to improve the possibility of the system to cope with fading.
The system will be used on the Olympus satellite both in the K_u (12/14 GHz) and in the K_a (20/30 GHz) band.

1. INTRODUCTION

One of the major problems for communications satellites operating at frequencies above 10 GHz is the high level of rain attenuation encountered.
Rain attenuation and depolarisation of a signal occur because individual raindrops absorb energy from radio waves and because some energy in the waves is scattered out of the propagation path. These interactions depend on the number of raindrops encountered and on their distribution of sizes and shapes.
At frequencies above 10 GHz, attenuation by rain has a significant effect on the availability of microwave links. Many techniques have been proposed to alleviate this problem and they are known by the generic title of *fade countermeasures.*

One idea is based on classical site diversity. It implies another station located at least 10 Km far from the principal station, interconnected by a terrestrial link. The solution is not an easy task because of the cost and complexity related in connecting two stations. Moreover, costly and permanently dedicated system resources are used only infrequently, so that the whole system results tremendously oversized for the clear sky conditions.

Another idea is based on providing a common pool of resources to be shared among all the ground stations that at a certain time experience a fade. This additional resource can be a fraction of the time frame interval in TDMA systems or a fraction of the bandwidth of the satellite transponder in FDMA systems, so that links affected by heavy attenuation can use a larger bandwidth for coded transmissions (crossband frequency diversity).
Even if these techniques may be used in combination, our interest is only devoted to a particular fade countermeasure technique operating in TDMA.

If the information rate of a satellite link is allowed to decrease during a fade, then adaptive FEC (Forward Error Correction) may be used as a fade countermeasure. Of course, adaptive coding may be used only on appropriate links that can tolerate a reduced throughput when faded.
When FEC is employed, during a fade the information rate is reduced and extra coding information is inserted into the channel, while the channel rate remains constant. A net gain is realised by the coding scheme, depending on the coding rate. Typical values are between 2 and 6 dB for coding rates between 7/8 and 1/2, respectively. *Punctured* codes represent an alternative

---

(1) Fifo Ordered Demand Assignment/Information Bit Energy Adaptive-Time Division Multiple Access

(and much cheaper) solution with respect to use optimised codes for each coding rate. The used technique is based on a K=7 convolutional encoder and a Viterbi decoder which, given a sequence of encoded bits, attempts a maximum likelihood sequence estimation to predict the original information bit sequence. Other rate codes can be derived from the 1/2 rate code by deleting (or "puncturing") bits periodically in the encoded sequence and inserting erasures at the decoder to produce a 1/2 rate sequence. In this way other fractional code rates can be produced based on the 1/2 rate code and making use of a 1/2 rate decoder with erasure input facility to decode the various rate codes. High data rates are used under unfaded conditions, when the signal-to-noise ratio is sufficiently high. Also the data rate is progressively reduced when deep fading occurs to make the decoder work with a suitable value of the E_b/N_o (bit energy over noise density) ratio and to allow the modem the acquisition in a reasonable interval of time.

The basic principle used by the present system to cope with different levels of the signal attenuation is the variation of the energy contained in an information bit. This is done by varying the transmission power, when possible, the data coding rate and the data bit rate.

2. THE NETWORK SCENARIO

End-user applications are supposed to run on hosts connected to a LAN. Different LANs are interconnected via satellite. The access to the satellite is obtained by means of the FODA/IBEA-TDMA satellite access scheme which runs on the Marconi R.C. hardware. The hardware consists of a TDMA satellite controller with a variable coding rate codec and a variable bit rate burst modem.
A protocol is provided (*GA-FO* protocol) for communications between the FODA/IBEA system and the outside environment [10].

Fig. 2.1 shows the network scenario.

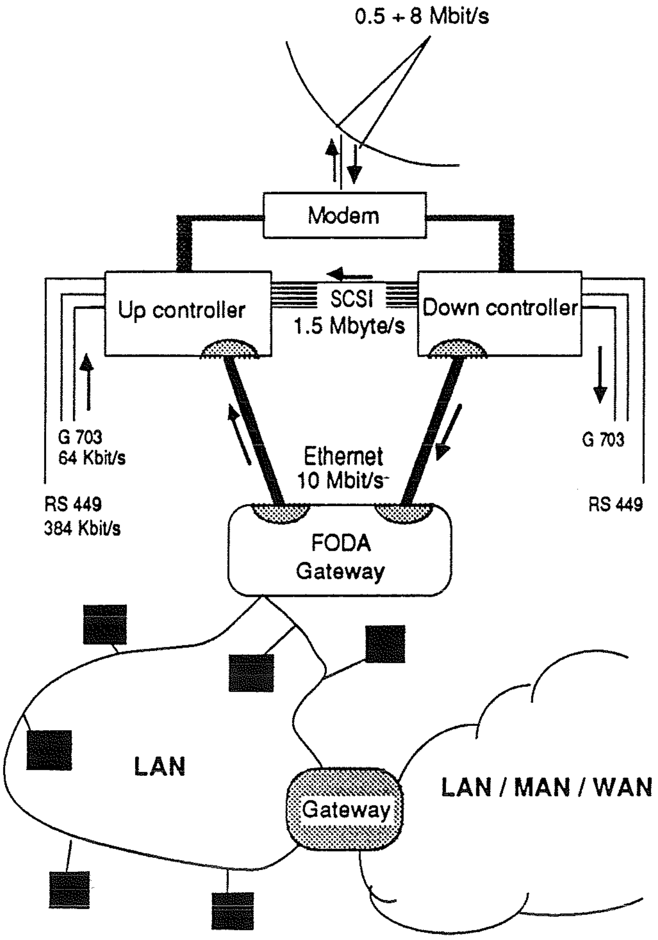


Fig. 2.1. Network scenario

3. THE TRAFFIC

FODA/IBEA allows simultaneous transmission of synchronous (*stream* data) and non-synchronous (*datagram* data) traffic.
Stream traffic, like voice, slow-scan TV, videoconferencing, etc., is characterised by a constant packet arrival rate. It requires short and fairly constant delay, it cannot tolerate out-of-order delivery of packets but it can tolerate occasional bit errors and dropped packets. In practice, stream traffic needs a fixed amount of bandwidth on as a regular basis as possible and the satellite network should maintain a low, constant delay on the arrival of information.
Datagram traffic is sub-divided into *bulk* and *interactive* type. Bulk data traffic (typically the file transfer) requires a large number of packets to be transmitted but the speed at which packets are sent and the delay introduced by the network(s) crossing are not critical constrains. Generally, it has not the rigid delay requirement of the speech and out-of-order delivery packets may be generally allowed. However, specially on a high delay network as the satellite one, the end-to-end throughput of such a traffic can be heavily impaired by bit errors or packet losses.
Interactive traffic (terminal access to computers, database enquiry, operator message exchange, etc.) demands error free, reliable delivery and short delays to guarantee acceptable response times. It often consists of short messages (a few characters) with unpredictable inter-arrival rates.

Table 3.1 is an attempt to distinguish among different types of traffic in terms of the key parameters of delay, throughput and quality of service requested by each type.

Traffic type	Throughput	Packet Length	Delay	QOS
interactive	low	low, variable	low	high
message	low	low, variable	medium	medium/high
mail	low/medium	medium, variable	high	medium/high
bulk	high	medium/high, constant	medium/high	high
fac-simile	medium	high, constant	medium	high
voice	medium	low, constant	low, constant	medium
slow scan TV	medium	high, constant	low, constant	medium
videoconference	high	high, constant	low, constant	medium

TAB. 3.1. Traffic characteristics

where:
Throughput (T) = low $(T < 1$ Kbit/s$)$
medium $(1$Kbit/s $< T < 100$Kbit/s$)$
high $(T > 100$Kbit/s$)$

Packet length (L) = low $(L < 128$ bytes$)$
medium $(128$ bytes $< L < 1$Kbit$)$
high $(L > 1$Kbit$)$

Delay (D) = low $(D < 0.5$s$)$
medium $(0.5$s $< D < 2$ s$)$
high $(D > 2$s$)$

Quality of service (Q) = low (10^{-4} BER, sequential)
medium (10^{-6} BER, sequential, error detection)
high (10^{-9} BER, sequential, error recovery).

4. THE HARDWARE

The hardware provided by the Marconi R.C. consists of a TDMA controller, including a variable coding rate codec, and of a variable bit rate burst modem. It is referred to as ***O-TDMA equipment*** (O stands for Olympus, because the first employ was planned to access the Olympus satellite). Detailed documentation can be found in [14, 15, 16, 17, 18].

4.1 The TDMA controller

The TDMA controller is split in two parts (Fig. 4.1): the *UP controller (UC)*, devoted to transmissions toward the satellite and the *DOWN controller (DC)*, devoted to receive data from the satellite.

The *transmit control processor hardware* consists of a MOTOROLA MVME147S-1 processor board and a transition module MVME712M. The processor board uses a 68030 processor card containing 4Mbyte of RAM. It runs at 25MHz and occupies one 4E wide VMEbus slot. The operating system supplied by Motorola on the board is called MVME147bug. The transmit control processor board acts as platform for the transmit control processor software which controls and monitors the functions of the transmit control unit. This includes, via the transition module, the VT100 operator console, SCSI, Ethernet and RS 232 interfaces.
The *transmit serial interface board* is a wire wrapped VMEbus compatible double Eurocard board (identity Y-35-9042). It acts as a buffer between the VMEbus and the three terrestrial interface ports of the transmit controller. The three ports are: a single high speed RS 449/ RS 422 port (high speed serial interface, at 384 Kbit/s), and two CCITT G.703 ports (low speed serial interfaces, at 64Kbit/s).
The *transmit modem interface* is controlled by the transmit control processor via a number of memory mapped ports which allow both reading and writing of control data. The circuit also provides the interface to the modem for data transmission and fault monitoring. The interfacing function is performed by two boards: the transmit modem interface and the line interface.
The transmit modem interface board is a wire wrapped VMEbus compatible double Eurocard board (identity Y-35-9041) 8W wide. It contains all the channel coding, framing and symbol rate selection functions. It processes data presented to it from the 32-bit VME data bus and also provides status information for circuit and modem monitoring purposes.
Data is either directed to the Data FIFO, which can store up to 512 bytes of data and control information, or to an event memory which is used to synchronise burst transmissions to the transmit frame. Control information is output to the Data FIFO prior to the data to be channel encoded. This control information sets the channel coding hardware to the appropriate mode. Data is sent to the FIFO encoded via the 32-bit VME data bus. Updating the Data FIFO is controlled by an interrupt which occurs when there is a transition in the Data FIFO half full flag. The transmit modem interface processes data presented to it from the 32 bit data bus. All data transfers are 32-bit word transfers between the transmit modem interface and the processor. The Data FIFO defines the content and timing of a burst relative to the burst start. The precise time at which bursts are sent to the modulator is determined by the *Transmit Event Memory (*TEM). This consists of two memory arrays organised in a ping-pong arrangement, each capable of storing up to 512 events. During one frame the software can update one site of the TEM whilst the other side is being used by the hardware. The events originated by the software are then used by the hardware in the subsequent frame. Events are programmed into the modem interface via a frame event memory which is addressed by the event number within the frame. New events are programmed into the off-line memory during the current frame and are actioned in the following frame. The updating must be performed before the end of the current frame. Each event within the event memory contains an 18 bit time code, which defines the time at which a particular action will take place (in 244 ns ticks from the start of the transmit frame), and a 14 bit function code. The transmit events are used, among other things, to open and close the burst gate and to set the modulator output level. A special function code can be used to define the end of the transmit frame by providing a reset pulse to the transmit frame counter. When the transmit burst gate is open formatted data is

sent from the CPU to the transmit modem interface under interrupt control. This data is then FEC encoded and scrambled if necessary. The FEC rates available are all based on a standard convolutional 1/2 rate code but puncturing logic allows additional code rates of 2/3 and 4/5. The hardware appends the necessary tail bits to flush the Viterbi decoder at the receive side and will, if required, append a short CRC to each transmitted DSB.

The line interface board is a double Eurocard size printed circuit board (identity Y-35-9037). This contains the line drivers/receivers for interfacing to the modem and also provides the 16.384 MHz reference clock, derived from a 32.768 MHz oven controlled crystal oscillator situated on the line interface board.

The *receive controller processor hardware* consists of a Motorola MVME147S-1 processor board and a transition module MVME712M. The processor board uses a 68030 processor card containing 4Mbyte of RAM. It runs at 25MHz and occupies one 4E wide VMEbus slot. The operating system supplied by Motorola on the board is called MVME147bug. The receive control processor board acts as platform for the receive control processor software which controls and monitors the functions of the receive control unit. This includes, via the transition module, SCSI, Ethernet and RS 232 interfaces.

The *receive serial interface board* is a wire wrapped VMEbus compatible double Eurocard board (identity Y-35-9053). It acts as interface between the VMEbus and the three terrestrial interface ports of the receive controller. The three ports are: a single high speed RS 449/ RS 422 port (high speed serial interface, at 384 Kbit/s), and two CCITT G.703 ports (low speed serial interfaces, at 64Kbit/s).

In order to avoid contentions, reading and writing to the memories is organised so that, whilst one half of the memory is being written to, it is the other that is being read from. This is known as *"ping-pong"* operation. Only the half of the memory which is not being read from appears in the VME address space. The interrupt service routine which is thus initiated determines which buffer is empty (by reading the status word) and then fills the first half of the memory via the VME interface Logic Cell Array (LCA). During this time the second half of the memory is being read from via the serial interface LCA.

Data is transferred between the receive control processor and the receive serial interface board via the VME Data Transfer Bus (DTB). A data transfer process is initiated by the receive serial interface board when any of the three dual ported memories becomes half full.

The *receive modem interface* and the *channel decoder* boards are two wire wrapped VMEbus compatible double Eurocard board (identities Y-35-9051 and Y-35-9052 respectively). Together they act as an interface between the VME bus and the modem control lines and perform all channel decoding functions. In the receive controller 4 bit soft-decision data received from the demodulator is passed to the FEC decoder where it is decoded if required. The receive hardware also provides a measurement of the estimated channel quality for each DSB by monitoring the recovered data soft decisions. The hardware simply observes the occurrence of particular soft decision levels and averages these over a sub-burst. Assuming a Gaussian distribution an approximation to the short-term BER can then be computed. This method is much faster than computing errors in the UW and it provides a channel estimate which can be used in adaptive fade countermeasures algorithms.

The receive modem interface is a processor controlled via a number of memory mapped ports which allow both reading and writing of status, control and data information between the processor and the hardware. The circuit also provides the interface to the modem for data reception and fault monitoring. The interfacing function is performed by three boards: the receive modem interface, the channel decoder and a line interface board.

The receive modem interface and the channel decoder boards are wire wrapped VMEbus compatible double Eurocards boards, each 8E wide. These contain all the channel decoding, framing and symbol rate identification functions. The receive modem interface processes data presented to it from the 32-bit VME data bus and also provides status information for circuit monitoring purposes. The decoded data stream is routed to the receive modem interface. This interface uses a Receive Event Memory (REM) to allow real-time reception and decoding of the received bursts. The REM is identical in structure to the TEM. The receive function code contains information on, amongst other things, the initial code rate and symbol rate of the bursts within the frame. A special function code can be used to generate a transmit frame pulse which will reset the event counter on the transmit controller. This is used by slave stations to synchronise their transmit frame to that of the master. Events are programmed into the modem interface via a frame event memory which is addressed by the event number within the frame. New events are programmed into the off-line memory during the current frame and are actioned in the following frame. The updating must be performed before the end of the current frame.

The line interface board is a double Eurocard size printed circuit (identity Y-35-9037). This contains the line drivers/receivers for interfacing to the modem and also provides the 16.384 MHz reference clock.

The codec supports variable coding rates: *1/2, 2/3, 4/5 and uncoded PSK*. Punctured codes, derived from the 1/2 convolutional encoder, are adopted. The decoder operates asynchronously at 8 Mbit/s information bit rate with 3 bit sign/magnitude soft decisions.
Guarantied error rates better than 10^{-4}, 10^{-6} and 10^{-8} for different services are offered respectively, by adapting the code rate to the signal/noise conditions.

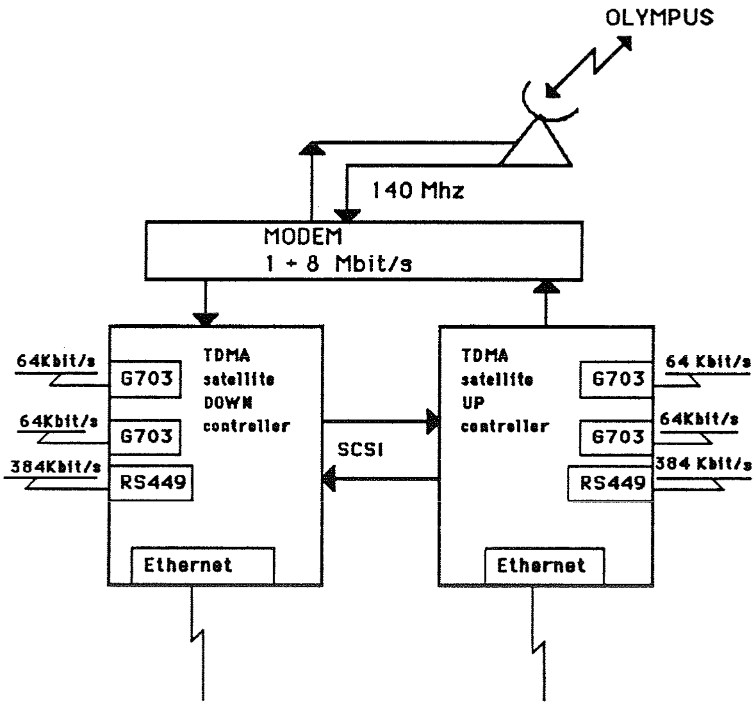


Fig. 4.1. Hardware configuration

Both the transmit and the receive controller hardware are detailed in [17].

4.2 The modem

The modem provided by the Marconi R.C. supports variable symbol rates: *1/2, 1, 2, and 4 Msymbol/s*, switchable on a sub-burst basis, with two different modulation schemes (BPSK and QPSK) to allow operations within a 5 MHz bandwidth. The bit rate results variable in the range 1-8 Mbit/s.
The modem consists of the following units:

Y-35-9030 A 19" x6U rack including a Vero PK110 power supply.

P-42-1504	A 21HP wide IF converter module. A 9HP wide blanking plate covering an unusable slot location.
Y-35-9031	Analogue interface. An 8HP double extended eurocard PCB.
Y-35-9032	FIR/Modulator. An 8HP double extended Eurocard wire-wrapped board.
Y-35-9038	Carrier estimator. An 8HP double extended Eurocard wire-wrapped board.
Y-35-9033	Timing estimator. An 8HP double extended Eurocard wire-wrapped board. An 8HP wide blanking plate covering a spare slot.
Y-35-9037	Line interface/clock generator. A double Eurocard PCB mounted on the rear panel.

A special feature of the modem is that it is capable of dynamically adjusting its transmission rate within a data burst. This allows the individual DSBs of a DB to have different symbol rates (and, hence, different energies) as required. The symbol rates available are 512, 1024, 2048 and 4096 Kbaud using either BPSK or QPSK modulation formats. A bit rate range of 512-8192 Kbit/s is thus available to the system. In order to meet the dynamic rate requirements the modem is implemented using digital signal processing (DSP) techniques.

The modem hardware is detailed in [18].

4.2.1. Stored waveform modulator

In an ideal modulator positive and negative impulses representing the two data states of the incoming binary data sequence are passed through a filter with Nyquist frequency response. Digitally this is equivalent to the convolution:

$$F(i) = \sum_{j=-\infty}^{\infty} I(i-j)\, C(j)$$

where $I(n)$ is the n^{th} data impulse (+-1 depending on the data state), $C(n)$ is the n^{th} filter coefficient and $F(n)$ is the n^{th} output sample. This function is implemented using a Finite Impulse Response (FIR) filter. As a consequence of Nyquist's sampling theorem the output of the digital modulator has aliases at the sampling frequency which must be removed by analogue anti-alias filters (AAFs) before transmission. Since the above convolution has only one output sample per data symbol it leads to serious AAF implementation problems because the aliases are at low frequency with respect to the wanted spectrum. This problem is overcome by increasing the input sampling rate by placing intermediate zero value samples in the input stream. In this way it is possible to obtain output sampling rates which are integer multiples of the data rate. Interpolation by a factor of four, for instance, would shift the aliases to four times their original frequency so that they become much easier to remove by analogue filtering. Symbol rate changes can conveniently be effected by changing the interpolation rate. In this way the output sampling rate , and consequently, the alias frequency, remains constant. The TDMA burst modulator has a fixed sampling clock of 16.384MHz. Interpolation rates of 4, 8, 16 and 32 thus provide the required transmission rates of 4096, 2048, 1024 and 512 Kbaud respectively.

The interpolated FIR can be implemented relatively simply by using a *stored waveform modulator* structure. The output results for all possible input sequences are pre-computed and stored in a Read Only Memory (ROM), This acts as a large look-up table which is addressed by the past n symbols of the incoming data sequence and an interpolation count. The resulting output sample is then available for transfer to the DAC.

For a two dimensional modulation scheme such as QPSK there are two sample sequences generated by two baseband FIR filters. These are converted to a real intermediate frequency (i.f.) for transmission using an analogue quadrature up-converter. The burst modulator also has an IF level control range of 20 dB in order to allow up-link power control.

4.2.2. Demodulator

The burst-mode demodulator is considerably more complex than the modulator. The received signal, polluted by noise and other effects, is first downconverted to two quadrature baseband signals by an IF converter. Following anti-alias filtering the signals are sampled by two Analogue to Digital Converters (ADCs) and the resulting complex sequence is passed to the digital processor. The complex samples are then filtered by a FIR filter, the response of which is selected depending on the expected burst symbol rate.

Once the received sample sequence has been filtered the original data stream must be extracted. In order to do this the demodulator must take estimates of several parameters from the received, noisy signals. For a phase modulation such as QPSK the parameters of interest are:

ω	an unknown carrier frequency translation (due to oscillator inaccuracy in the satellite and the earth stations;
ϕ	an unknown carrier phase shift (modulo 2π);
τ	an unknown timing phase shift (modulo T).

The carrier frequency error consists of two components. The downlink frequency error ω_d is due to the satellite frequency conversion error and the downconverter in the local receive station. This error can be up to +- 40 kHz but it applies to all of the bursts in the frame. The demodulator removes this by an initial AFC sweep at the start of operation and tracks the slow variations thereafter. The uplink frequency error ω_u is more of a problem. It is caused by the variations in transmit frequency at the remote stations and is thus different for each burst in the frame. In a typical system ω_u can be of the order of +-4 kHz. The value of ω_u must be estimated very rapidly at the start of each burst.

In order to allow parameter estimation, and thus data demodulation, before the arrival of the UW, each burst is preceded by a short preamble. The lengths of each component of the preamble can be changed under software control and are set to provide a certain level of performance under given conditions.

The parameters ω_u and ϕ are estimated simultaneously at the start of each burst using the unmodulated carrier preamble. Two types of estimator were considered. The *feedback* estimator makes an estimate of the error between the wanted phase and ϕ and adjusts the incoming phase to minimise the error. The *feedforward* estimator makes absolute estimates of ϕ and then passes these forward to a larger stage where an appropriate correction is made. The feedback estimator works well under low signal-to-noise conditions and can accommodate large frequency errors; however, in a burst mode system, it does have a major problem called *hang-up*. This phenomenon leads to occasional very long acquisition times when the initial phase error is close to π. This is not acceptable for a burst-mode system where reliable acquisition in a limited time is necessary. The feedforward system does not suffer from hung-up but, unfortunately, it is not particularly suited to situations where the initial frequency offset is large. In order to overcome these problems, this modem uses two digitally-implemented feedback estimators which are initialised to different states just prior to the expected reception of a burst. Since the initial phase of each estimator is different, they cannot both suffer from hung-up and so one will always acquire within the time available.

The symbol phase, τ, is estimated using the reversals present at the end of the preamble. Several estimators matched to different clock phases are used and the phase giving the largest output is used to initialise the clock tracking loop. Once the symbol phase has been estimated, the demodulated data is available to the receive controller.

4.3. Hardware restrictions

This hardware allows users to implement a wide range of TDMA systems in software but it does imposes some restrictions. These were necessary since, in some cases, the software would be unable to react quickly enough to external events.

- Each burst must start with a carrier and bit timing recovery sequence (CBTRS). This is actually a restriction of the modem.

- The frame must include a reference burst (RB) containing the master unique word (MUW). The MUW maintains synchronisation of the receive hardware frame counter. Apart from the MUW the remaining content of the RB is unimportant to the hardware. Only one MUW must appear in each frame. The maximum frame length is 64 ms.

- Each data burst must consists of a control sub-burst (CBS) followed by a number, possibly zero, of data sub-bursts (DSBs). The CSB is decoded by the hardware and provides information necessary for the reception of the following DSBs.

5. THE *FODA/IBEA* SATELLITE ACCESS SCHEME

The design of the FODA/IBEA-TDMA satellite access scheme is based on a centralised control supported by a control station (*master*).
The remainder active stations in the satellite network act as slaves. It is the master station's responsibility to govern the orderly operation of the network, controlling resources and maintaining the synchronisation of the slaves. Although there is only one master station at each time in the network, all the controllers are capable of operating as master.

The master:

a) allocates time within the TDMA frame for the stream and the datagram transmissions of the slaves,
b) maintains the synchronisation of all the stations within the network,
c) maintains the optimum transmit power level that is used by all the slaves as a reference level,
d) uses the frame space allocated to itself to send data over the network in the same way as a slave station.

The slave:

a) adjusts the transmit power level keeping the master a reference,
b) sends to the master allocation requests for stream and/or datagram transmissions,
c) uses the frame space allocated to it by the master to send data over the satellite network,
d) chooses the symbol rate and the code rate for all the data to send, according to the fade level of each link,
e) broadcasts its fade level.

The master operates on a signalling channel. The signalling channel may be realised by using a dedicated channel or, as in the current implementation, inside the TDMA time frame. The slots for data transmissions to the satellite are assigned on demand, following certain criteria discussed in 5.3.

The master station may be replaced, in case of fault, by any traffic station among those declared available to assume this task. At any time a traffic station can decide to renounce to become the new master. The master broadcasts the physical address of the station it can be replaced by in case of fault. The successor is the first active station (which declared its availability) in the stations list maintained by the master. A station can refuse, at any time, the possibility to become the new master. The current master reports this condition in the status associated to that traffic station and the next available master successor is selected, if necessary.

5.1 The FODA/IBEA frame

The FODA/IBEA frame is 20 ms long. As shown in Fig. 5.1, each frame contains:

1) **One** ***reference burst,*** sent by the master station in order to assign the time allocations for the stream and/or the datagram transmissions.
The reference burst is always sent at fixed bit and coding rates. The values of 2 Mbit/s and 2/3 coded, respectively, have been chosen to start with.

2) **Many** *transmission slots (or transmission windows)* for sending stream and/or datagram data. Just one transmission slot is assigned to a requesting station, if the transmission bit rates of stream and of datagram data are such that both of them can be sent together. When sent in the

same transmission slot, one transmission overhead (preamble + control sub-burst) is saved. The part of each transmission slot devoted to the stream data remains unchanged in size (once assigned), while the part devoted to the datagram data may change in size at each frame. Therefore, the transmission window(s) must be recalculated by the master at each frame.
No time holes are left in the frame as far as the assignments are concerned.
In each frame, *two fixed-length slots (control slots) are assigned* on a round-robin scheduling basis *to the first two stations* (among all the active stations) *which had no assignments in that frame.* The first station scheduled for the control slot will be assigned the first control slot; the second station the second one. The control slots are used to guarantee the possibility to make the requests, when the piggy-back with the data is impossible because the station has no assignments. *The control slots are assigned at 2Mbit/s.* Their position is in any part of the frame.
If all the stations have an allocation in a frame, the space devoted to the control slots is shared between the first two stations in scheduling for the allocation of the control slots.

3) **One *first access slot (FAS)*, every *32* frames.** It is devoted to allow a new station to enter the network. It is used in contention among all the stations which want to become active. In the frame in which no FAS slot is present, no control slots are allocated. This slot is sized as the two (missing) control slots. Really, it is has the same size of one control slot plus the uncertainty due to the current satellite position with respect to the nominal satellite position. *The FAS has a fixed position inside the frame (before the end of the frame). It is assigned at 2 Mbit/s.*

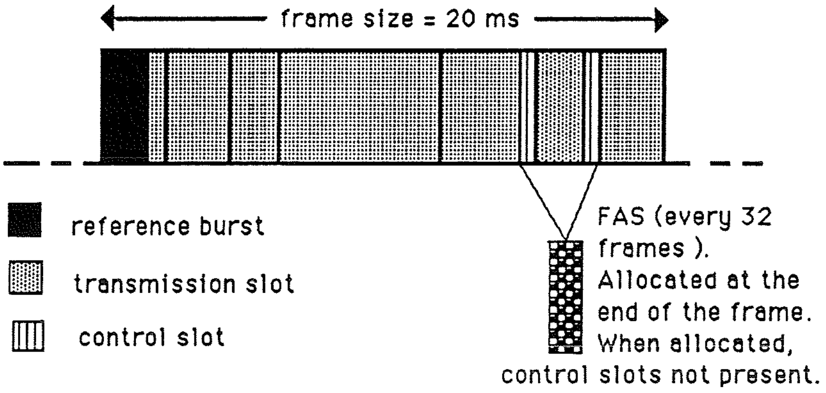


Fig. 5.1. The FODA/IBEA frame

We will use the term *stream sub-frame* to indicate the amount of frame devoted to contain *the sum of the stream allocations.* In the same way, *datagram sub-frame* indicates the amount of frame devoted to contain *the sum of the datagram allocations..*
The stream sub-frame extends up to an upper limit B_1. If no stream traffic is present, the datagram sub-frame can occupy almost the whole frame. When fades are experienced, the stream transmission is privileged and space is found in the frame to allow the stream data enlarging by increasing, if necessary, the stream sub-frame upper limit up to a B_2 value. The datagram sub-frame is squeezed as a result. The data enlarging is due to the choice of the most suitable code rate (among the supported ones) to counter the fade in course. If coding is insufficient, the data rate is reduced in one octave steps.

5.2 Classes of service and redundancy factors

Data to be transferred between two applications running over two different LANs interconnected via the satellite must satisfy some requirements relevant to the quality of the requested service:

a) *the typical data end-to-end delay,*

b) *the maximum jitter of the packet inter-arrival time,*

c) *the requested bit error rate (BER).*

In the present system the first two parameters are really not negotiable. In case of stream, the delay depends on the round trip time(RTT) plus a fraction of the time frame (roughly 300 ms, in total). The maximum jitter can be assumed one time frame long.
In case of datagram, both the delay and the jitter depend strongly on the traffic conditions of the overall system and on the saturation control mechanism. In no case, anyway, these parameters can be specified by the application.
The BER, on the contrary, must be specified by the application to choose the quality of the data communication link. A requested range of BER is specified by means of a class of service value (COS). Four classes of service are envisaged, as shown in Tab. 5.2.

COS	BER not >	BER not <	Example of type of data
1	10^{-8}	----	reference burst; broadcasted control inf.; control sub-bursts; headers, reliable data, bulk data
2	$3 * 10^{-7}$	10^{-8}	reliable data: bulk data; special voice/video; interactive data
3	$3 * 10^{-5}$	$3 * 10^{-7}$	standard voice/video
4	10^{-3}	$3 * 10^{-6}$	degraded voice

TAB. 5.2. The classes of service

When a fade of the signal occurs due to bad atmospheric condition, the BER specified by the sending application can be maintained by using the most suitable couple of bit and coding rates. The operating E_b/N_o value must be sufficiently high to allow a suitable high probability of the modem acquisition. This is translated into the probability of the UW detection.
The characteristics of the codes supported by the hardware are reported in Fig. 5.3 and Fig. 5.4, where measured and extrapolated values are shown, respectively(2).

---

(2) Fig. 5.3 is reproduced with permission of GEC Marconi Research Centre (UK). Fig. 5.4 is derived by extrapolation from Fig. 5.3.

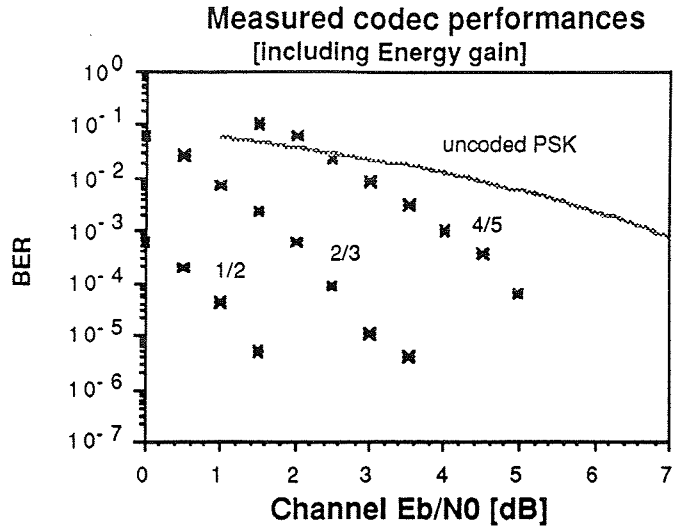


Fig. 5.3. Codec measured values

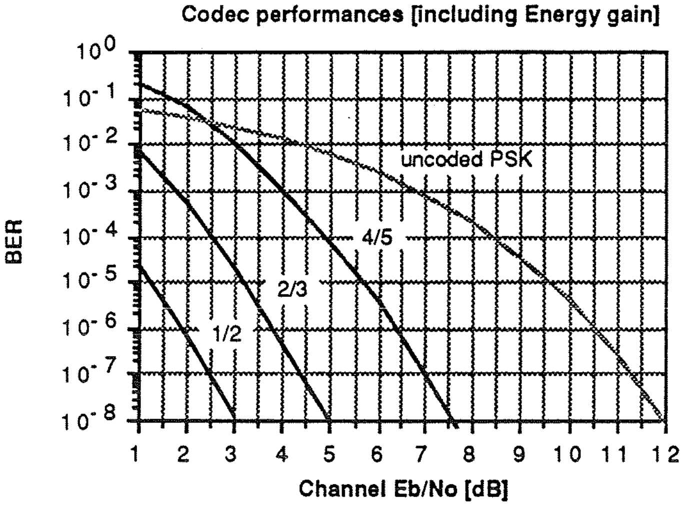


Fig. 5.4. Codec extrapolated values

The Redundancy information factor *Ri* is the ratio between the information bit energy of data sent at certain bit and coding rates and the information bit energy of the same amount of data sent uncoded at 8 Mbit/s. Ri can be expressed as the product between the redundancy coding *Rc* and the redundancy speed *Rs*. Ri represents the data enlarging due to the increase of the code rate and to the possible reduction of the bit rate. When an increased attenuation of the signal must be compensated (i.e. maintaining the same BER value of that type of data), it is preferable to reduce the coding rate first (taking advantage of the coding gain) rather than reducing the bit rate. This one must be halved only when E_b/N_o drops under a minimum value, necessary for the burst mode acquisition.

The fade level represents the number of dB of the available C/N_o (carrier power over noise density) ratio below the theorical value of 81 dB assumed as fade level 0. When operating at fade level 0 at the bit rate of 8 Mbit/s, the E_b/N_o ratio is 12 dB. This value of E_b/N_o allows the reception of uncoded data with a BER lower than 10^{-8}.

The best combinations of coding and bit rates have been chosen by keeping into consideration the

BER requirements of the four classes of services. Such combinations are shown in Tab. 5.5, considering 4 dB (5 dB actually measured on the channel, minus 1dB of modem implementation margin) the minimum Eb/No value necessary for the modem acquisition :

F[dB]	Q[dB]	Mbps	Rs	Rc_1	Ri_1	Rc_2	Ri_2	Rc_3	Ri_3	Rc_4	Ri_4
0	12	8	1	1	1	1	1	1	1	1	1
1	11	8	1	5/4	5/4	1	1	1	1	1	1
2	10	8	1	5/4	5/4	5/4	5/4	1	1	1	1
3	9	8	1	5/4	5/4	5/4	5/4	1	1	1	1
4	8	8	1	5/4	5/4	5/4	5/4	5/4	5/4	1	1
5	7	8	1	3/2	3/2	5/4	5/4	5/4	5/4	1	1
6	6	8	1	3/2	3/2	3/2	3/2	5/4	5/4	5/4	5/4
7	5	8	1	3/2	3/2	3/2	3/2	3/2	3/2	5/4	5/4
8	4	8	1	2	2	3/2	3/2	3/2	3/2	5/4	5/4
9	6	4	2	3/2	3	3/2	3	5/4	5/2	5/4	5/2
10	5	4	2	3/2	3	3/2	3	3/2	3	5/4	5/2
11	4	4	2	2	4	3/2	3	3/2	3	5/4	5/2
12	6	2	4	3/2	6	3/2	6	5/4	5	5/4	5
13	5	2	4	3/2	6	3/2	6	3/2	6	5/4	5
14	4	2	4	2	8	3/2	6	3/2	6	5/4	5
15	6	1	8	3/2	12	3/2	12	5/4	10	5/4	10
16	5	1	8	3/2	12	3/2	12	3/2	12	5/4	10
17	4	1	8	2	16	3/2	12	3/2	12	5/4	10

TAB. 5.5
minimum value of Eb/No for modem acquisition = 4 dB

where:

F[dB]	is the fade level expressed in dB;
Q[dB]	is the channel quality (Eb/No) expressed in dB;
Mbps	is the data rate expressed in Mbit/s;
Rs	is the Redundancy speed factor (8/current speed);
Rc_k	is the redundancy code factor for the class of service #k (1/current used code);
Ri_k	is the redundancy information factor for the class of service #k (Rs * Rc).

Fig. 5.6 shows the behaviour of the redundancy levels (1-16) for the four classes of services with respect to the fade conditions.
From Tab. 5.5 and from Fig. 5.4 it results that the 1/2 code is used by the class of service 1 only, when the minimum Eb/No value is reached.

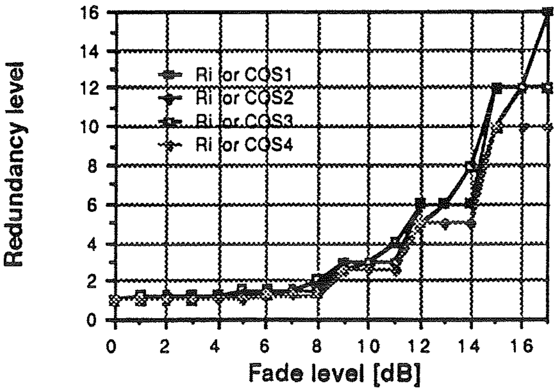


Fig. 5.6. Redundancy level behaviour

If the minimum value of Eb/No necessary for the modem acquisition is fixed to 6 dB (7 dB actually measured on the channel, minus 1dB of modem implementation margin), the table 5.5 becomes table 5.7.

F[dB]	Q[dB]	Mbps	Rs	Rc_1	Ri_1	Rc_2	Ri_2	Rc_3	Ri_3	Rc_4	Ri_4
0	12	8	1	1	1	1	1	1	1	1	1
1	11	8	1	5/4	5/4	5/4	5/4	1	1	1	1
2	10	8	1	5/4	5/4	5/4	5/4	1	1	1	1
3	9	8	1	5/4	5/4	5/4	5/4	1	1	1	1
4	8	8	1	5/4	5/4	5/4	5/4	5/4	5/4	1	1
5	7	8	1	3/2	3/2	3/2	5/4	5/4	5/4	1	1
6	6	8	1	3/2	3/2	3/2	3/2	5/4	5/4	5/4	5/4
7	8	4	2	5/4	5/2	5/4	5/2	5/4	5/2	1	2
8	7	4	2	3/2	3	3/2	3	5/4	5/2	1	2
9	6	4	2	3/2	3	3/2	3	5/4	5/2	5/4	5/2
10	8	2	4	5/4	5	5/4	5	5/4	5	1	4
11	7	2	4	3/2	6	3/2	6	5/4	5	1	4
12	6	2	4	3/2	6	3/2	6	5/4	5	5/4	5
13	8	1	8	5/4	10	5/4	10	5/4	10	1	8
14	7	1	8	3/2	12	3/2	12	5/4	10	1	8
15	6	1	8	3/2	12	3/2	12	5/4	10	5/4	10

TAB. 5.7
minimum value of Eb/No for modem acquisition = 6 dB

From table 5.7 it results that the 1/2 coding rate is never used.

5.3 The requests and the assignments

Once active, a station can make requests for stream slots (stream channels) and/or for datagram slots. Normally, the requests are piggy-backed with the data in the transmission slots. If no transmission slot is assigned to the station, it can use the control slot, when assigned by the master.

The station *stream request is made only once* and, if accepted, it is considered valid until an update request or an explicit relinquish request is issued. The request is made as a *multiple of the 32-bit word.*
Each stream application must send a request to the FODA/IBEA system indicating the number of requested stream channels Cr, the minimum acceptable number of assigned stream channels Cm (which may coincide with Cr) and the requested class of service, expressed by means of a number ranging from 1 to 4. The request to the FODA/IBEA system is done by issuing a command of the GA-FO protocol.
The station software provides to assemble together all the incoming Cr and sends to the master a global request, sum of all the received Cr. The request includes also the computed transmission overhead. The master station grants the stream requests received from the active stations up to the B_1 upper limit in the stream sub-frame. The boundary B_1 is not exceeded in unfaded conditions.
If the master grants exactly the requested number of stream channels (the granting is specified in the reference burst), the system provides to distribute the assigned channels among the requesting stream applications according to their Cr requests. The control station ignores both the Cm and the COS values which are used by the requesting station to maintain the same stream transmission characteristics even in presence of signal fading.

When a fade occurs, the FODA/IBEA system tries to maintain the already set-up stream transmissions at the specified BER. To compensate the signal fade, the stream transmissions need more space in the time frame to send the same amount of information. Therefore, the station in fade sends to the master an update of the original stream request in order to obtain more stream channels. This special update (due to fade conditions) is specially flagged to distinguish it from a normal update. The control station tries to grant the new request inside the B_1 upper limit. If insufficient, the upper limit of the stream sub-frame is increased up to the B_2 value, squeezing the datagram sub-frame. The increasing of the stream sub-frame upper limit is only allowed in case of fade, not in order to grant requests from new applications. When the stream sub-frame upper limit is in B_2, stream requests coming from new applications are refused. The stream sub-frame upper limit is moved back from B_2 into B_1 when all the fade conditions are overcome.

If the increased size of the stream sub-frame is not sufficient to satisfy the increased requests, the system notifies (by using the GA-FO protocol) the stream application(s) about the necessity of reducing the requested bandwidth up to the declared Cm value. This is possible only if Cm is less than the requested Cr value (compressible applications). After receiving the ack for compression from the stream application(s), another attempt is made by the faded station, sending a new request to the master. The new request is the sum of all the possible Cm values and of the incompressible Cr values. If also the new request cannot be entirely granted, all or part of the stream applications will carry on at degraded BER conditions. It is up to the application itself the decision whether to continue the session at a degraded performance or to give up, leaving the granted stream channels to other users.

Fig. 5.8 briefly shows the stream assignment mechanism adopted by the master station.

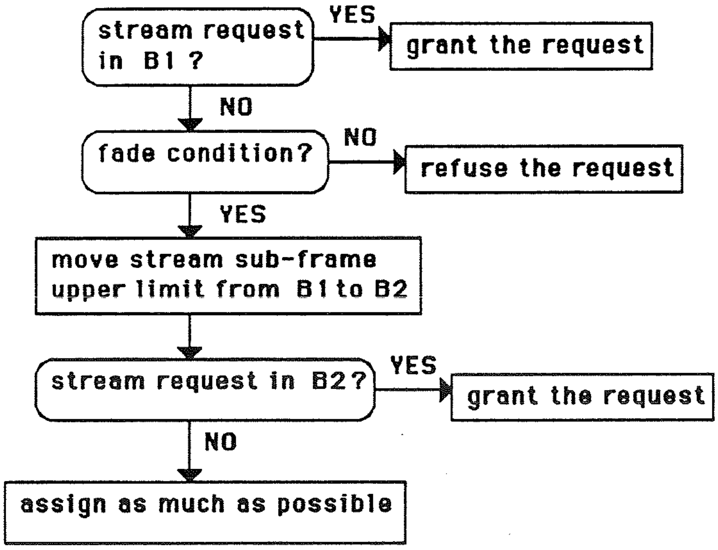


Fig. 5.8. Stream assignment mechanism

The station makes the requests for *datagram slots* (UR) at any transmitting chance, but not more frequently than once in a minimum period of time. The request is *expressed as a multiple of 16 32-bit words.* It takes into consideration both the instantaneous traffic entering the station from the various applications (*TRAFFIC)* and the amount of data lying in the station and waiting to be sent to the satellite (*BACKLOG*).

The requests are organised by the master in a circular queue, cyclically scanned to compute the amount of time of each assignment. New datagram requests are put at the current beginning of the list in order to be scanned as first ones. This allows to reduce the delay time between the first request and the assignment after a period of no transmissions. Any further datagram request from the same station (other than the first one) is considered an update and replaces the previous value.

The length of the assigned time slots is proportional to the request in a range of values between a minimum and a maximum threshold. The proportionality is obtained by assigning a percentage of the request. The percentage is proportional to the number of active stations, with 10% as minimum and 50% as maximum. After each assignment, the user datagram request UR is decremented by the assignment itself (A) and the next request is analysed, if space is still available in the frame. The first assignment that does not fit entirely into the current frame will be analysed again as first assignment in the next frame and the rest of the computed amount is then assigned. All the space up to the end of the frame (if insufficient for a minimum assignment) is given as an over-assignment to the last processed station.
If space is still available in the frame for datagram assignments and (after all the assignments) the queue of the datagram requests has become empty, the available space is divided among all the stations which had the datagram assignment in that frame (i.e. among all the stations which in the current reference burst the master is going to prepare, have a datagram assignment different from zero). This features provides an easy sharing of the spare time (bandwidth), among all the active stations. This allows the stations to absorb an amount of traffic abrupt variations, when the satellite channel is scarcely loaded.

Analytical studies and the simulation of the entire system [11, 12], together with the real system experience (at 2Mbit/s on the EUTELSAT-F2 satellite) allowed the calibration of the coefficient of proportionality and of the two thresholds. A resulting suitable expression for UR is:

$$UR = BACKLOG + H * TRAFFIC$$

where H is a temporal constant. The simulation results of Figs. 5.9 and 5.10, obtained loading the channel with Poisson generators of datagram traffic for 10 stations, show that *the best value of His 0.4 s for the FODA/IBEA system* (we remind that for the fixed rate FODA system the best value of H resulted 0.5 s for a 31.25 ms frame).

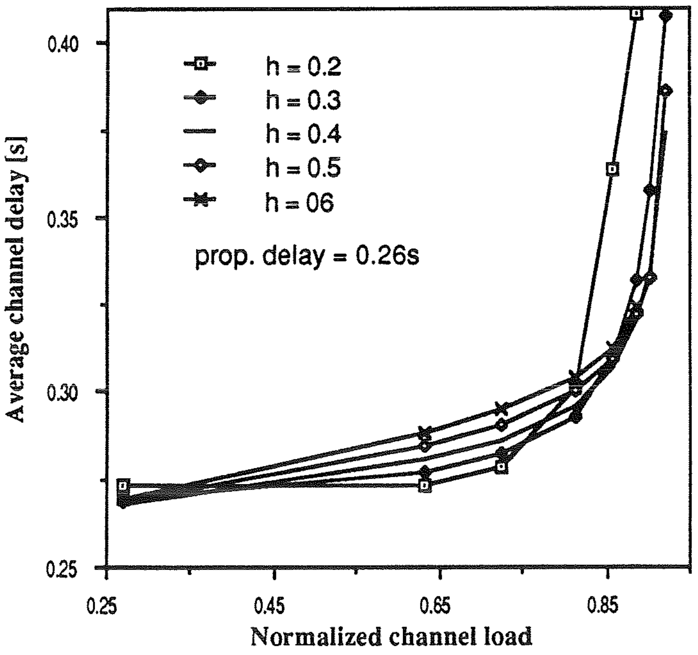


Fig. 5.9. End-to-end delay averaged over 30s for various values of H. 10 stations . Poisson datagram traffic.

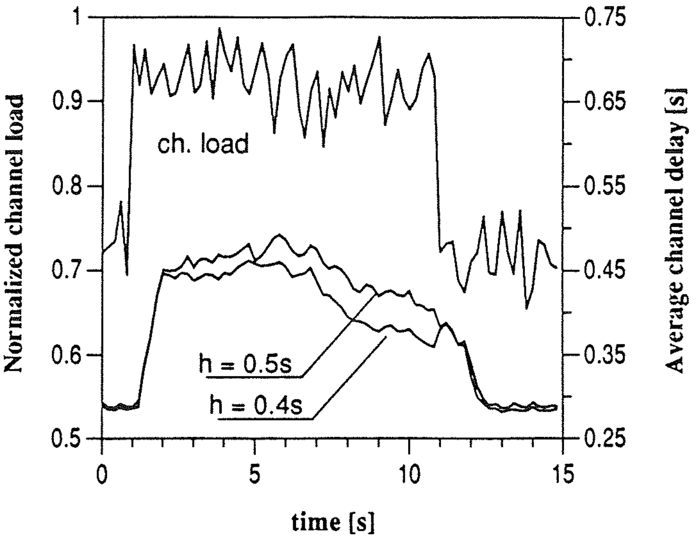


Fig. 5.10. Channel delay averaged over 10 stations.
Poisson datagram traffic.
A step of traffic of 20% is applied to one station for 10 s.

The datagram user request is not comprehensive of the transmission overhead due to preambles, headers and guard times. This overhead is added to each datagram assignment by the master station.

Fig. 5.11 sketches the datagram assignment mechanism.

Fig. 5.11. Datagram assignment behaviour

As far as the datagram transmissions are concerned, fading conditions cause an increment of the actual backlog and of the instantaneous traffic. This automatically increases the station request UR, making an attempt to get more bandwidth. Due to the increase of the request itself and/or to the eventual compression of the datagram sub-frame (to grant more stream channels), the overall capacity of the datagram may result sensibly reduced and particularly under heavy loading conditions of the system. An efficient action of the channel saturation control system is requested to avoid congestion.

A rather simple method to avoid saturation is to block the growth of the backlog for a while, by exercising a backpressure on the remote users, when a situation dangerous for congestion is detected. Since datagram data is collected from high speed networks, the only effect of this procedure is to slow down the datagram traffic coming from the remote hosts for a convenient interval of time. To detect saturation, the user must be able to compute its own transmission queuing time at frequent intervals of time. The mechanism for blocking the backlog is activated as soon as the estimated delay crosses upwards a certain upper threshold and it is deactivated when a lower threshold is downwards crossed.

The following procedure is adopted by each station to make a coarse estimation of the queuing delay.

The channel capacity reserved for datagram (C_d) is calculated decrementing the total channel capacity by the total capacity assigned for stream transmissions: $C_d = C - C_s$.

Let D_c be the portion of C_d assigned to a certain user U. It is the ratio between the amount of time of its own assignment and the total amount of time assigned to all the running stations to send datagram traffic (assignment cycle). The delay D is approximately estimated as:

$$D = BACKLOG/(C_d * D_c)$$

where all the variables are considered averaged over a suitable interval of time.

5.4 The transmission window(s) set up

Each station finds the allocation of its own transmission window in the reference burst. The assigned allocation includes generally the stream request plus a percentage of the datagram request. In both the stream and the datagram requests, the preamble bit rate of the type of data relevant to the request is specified. As a station can send data to different destinations, the preamble bit rate must match the needs of the destination station experiencing the worst fade conditions. The reference burst is sent in broadcast, so each station is informed about the burst time plan of all the stations sending data in the next frame. This data is received a round trip delay time later (14 frames). The burst time information plan is used to preset the modem acquisition at the specified symbol rate of each expected data burst and to set up the relevant unique word acquisition windows.

In general, the trend is to set up just one transmission window for sending both stream and datagram data. This is possible only if the preamble bit rate of the stream assignment is *lower or equal* to the preamble bit rate of the datagram assignment. In this case, in fact, stream data has to be transmitted with worse transmission characteristics than the datagram data and the worse preamble bit rate (the one of the stream data) can be used for both the data types without stealing anything to the stream assignment.

On the other hand, if the preamble bit rate specified in the stream assignment is *greater* than the preamble bit rate of the datagram assignment, then two consecutive but separated windows must be set up, one for stream and one for datagram data. This is because the adoption of the worse preamble bit rate (the one specified in the datagram data) should deprive the stream allocation of part of the allocation itself, due to the unconsidered preamble enlarging.

5.5 The FODA/IBEA transmissions

It is convenient to give here some definitions. *Data burst* (DB) is the amount of information which can be transmitted to the satellite by a certain station during its transmission window. The transmission window is the time slot assigned to a station by the master station for sending stream and/or datagram data. A burst may contain data addressed to different destination stations. A data burst is composed by *n* *data sub-bursts* (DSB) (255 as maximum), each one with individual destination station and with individual transmission characteristics (bit and coding rates). 2 is the minimum number of sub-bursts forming a burst because each data burst must be described by a control sub-burst. Each data sub-burst is associated a satellite header describing the relevant data. All the headers of the data sub-burst are compacted in the control sub-burst. Another area, called *channel control area* (CCA) is included, when necessary, in the control sub-burst to send the assignment requests and/or to send other control information [10, 13].

A stream sub-burst may consists of more than one packet (stream applications sending more than 1 packet every 20 ms). A datagram sub-burst consists of only one data packet or a fraction of it.

The *reference burst* (RB) is a particular type of burst, sent in broadcast at the beginning of each frame by the control station. It is sent for synchronisation purposes and to give the transmission times plan to the stations allowed to transmit in the frame following the one where the reference burst is received. The reference burst is the only burst not preceded by the control sub-burst.

Fig. 5.12 shows the format of each data burst transmission.

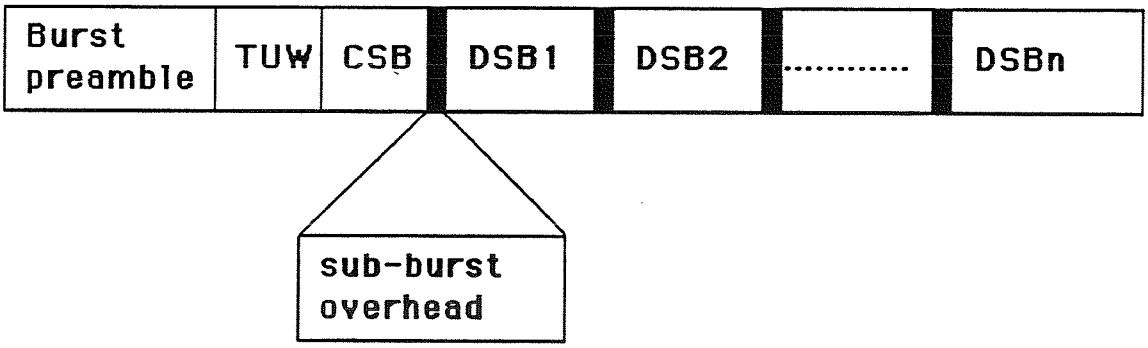


Fig. 5.12. FODA/IBEA data burst format

The *preamble* sequence consists of an initial segment of unmodulated carrier (carrier) followed by reversals. The carrier (9 32-bit words) is sent as successive binary "00"s and used in the receive modem to recover the carrier. The reversals (1.5 32-bit words) are sent as successive "11"s "00" pairs and are used in the receiver for clock recovery. This corresponds to alternate "1" and "0" for each of the I and Q channel of the QPSK system.
The preamble pattern is followed by the *unique word (UW)* field.

The *UW* is a sequence of ones and zeros (48 bits long), on both the I and Q phases of the carrier, selected to exhibit good correlation properties. It serves to mark the beginning of the transmitted data channels. The instant of occurrence of the UW correlation spike marks the symbol time reference for decoding the information in the data part of a burst. Successful detection of the UW is necessary to mark the time of occurrence of the reference burst and to establish the time reference for decoding the received bursts.
The unique word type and the phase ambiguity resolution are both performed using special UW formats. The unique word is based on UW and UW* combinations and four different unique

combinations may be formed by using a binary sequence UW followed by either the same sequence or its complement (UW*) on each the I and Q channels.
The combination used by the master station to send the reference burst is called MUW (master UW). The combination used to send data bursts is called TUW (Traffic UW).

Both the preamble and the UW are always sent uncoded.

The *control sub-burst* (CSB) conveys information about each of the subsequent data sub-bursts in a burst. Optionally a number of extra words which could be used to convey status information about the conditions of transmission of the burst are also contained. *For each data sub-burst in a burst, the control sub-burst specifies the word length and the used bit and coding rates.* As an incorrect decoding of the control sub-burst provokes the discarding of all the data sub-bursts, the CSB must be always transmitted at the maximum security. The satellite headers are included in the control sub-burst. The format of the control sub-burst and its bit definitions can be found in [13].

5.6 RB, CS and FAS occupancy

In Tab. 5.13, the *reference burst occupancy* is reported for different numbers of active stations. The format of the RB can be found in [13].
The RB is always sent at 2 Mbit/s, 2/3 coded.

	4 stations	*8 stations*	*16 stations*	*32 stations*	*64 stations*
RB byte length	24	44	85 rounded to 88	167 rounded to 168	331 rounded to 332
RB 2/3 coded byte length	36	66	132	252	498
overhead (in bytes)	48 (preamble+UW uncoded) + 8 * coding = 60	60	60	60	60
total bytes	96	126	192	312	558
max symbol rate symbols	1536	2016	3072	4992	8928
ms occupancy	0.37	0.49	0.75	1.21	2.17
frame %	1.85	2.45	3.75	6.05	10.85

TAB. 5.13. RB occupancy

The *first access slot* must be accessed by any station in the Olympus coverage area. It is sent once every 32 frames and the total access space is the sum of the two control slots which are not present when FAS is present. The FAS must allow a new station to enter the system for the first time.
The space devoted to the FAS is computed by the master station as sum of two control slots.
Each control slot is sized considering the minimum quantum of information which must be sent at 2 Mbit/s, 2/3 coded, i.e:

- preamble + UW = 12 (32 bit) words = 48 bytes (uncoded)

  \+

- 20 bytes 2/3 coded = 30 bytes.

It corresponds to a total of 78 bytes = 1248 Max symbol rate symbols = 0.30 ms = 1.5 % of the frame.

As the FAS occupies the space devoted to 2 control slots, the access jitter to the FAS is ± 150 μs (= 0.150 ms).

5.7 The link budget for Olympus

The choice of the maximum system bit rate of 8 Mbit/s was due to the necessity of limiting the capacity, and consequently the cost, of the stations. The other economic requirement of fully exploiting the transponder capacity thus imposes a multicarrier access to the transponder itself. Each carrier can be shared in TDMA, using FODA/IBEA or similar systems. The various systems may operate autonomously or may belong to a global MF-TDMA system as, for example, one of those presented in [25].
In order to limit the intermodulation interference due to multicarrier access, the satellite transponder HPA must be sufficiently backed-off. The IPDF (input power flux density) at the satellite must be kept constant and the transponder gain is set in such a way to operate with the chosen back-off.

Table 5.14 shows an example of link budget, using Olympus in K_a band and 2.5 m antennas equipped with the tracking feature. Three carriers are considered.

Up-link freq. [GHz] (CH1)	28.072255	Number of carriers	3
Down-link freq. [GHz] (CH3)	19.475	Total IPDF [dBW/n^2]	-102
E/S EIRP [dBW]	73	Input Back-off [dB]	8
E/S HPA Back-off [dB]	3	Satellite EIRP [dBW]	55.5
Up-power Control Margin [dB]	13	Output Back-off [dB]	4.5
Satellite G/T [dBK]	14	E/S G/T [dB/K]	27.3
C/T at satellite input [dBW/K]	-143.5	C/No at E/S receiver [dBHz]	82.6
Intermodulation C/T [dBW/K]	-140	Eb/No at 8Mbit/s [dB]	13.5
Total Up-link C/T [dBW/K]	-145	Modem implementation margin [dB]	1.5
Up-link Eb/(No+Io) [dB]	14.4	Eb/No in clear sky conditions	12

Table 5.14. Link budget for the Olympus K_a transponder.
Three carriers at 8Mbit/s access the transponder in FDMA.
The 2.5 m E/S is equipped with a 70 W HPA.

A C/T ratio due to intermodulation interference of -140 dBW/K has been assumed. This figure must be confirmed experimentally. In this example the up-link power control range is 13 dB. The value of the Eb/No ratio (12 dB) resulting from Tab.5.13 is assumed as the reference unfaded value. It allows uncoded transmissions at 8Mbit/s with a BER of 10^{-8} for up-link fade conditions ranging from 0 dB(clear sky) to 13 dB.
The up-link power control is realised, on each carrier system, as follows. The power level of the master is assumed to be the reference level for all the stations. Each station is able to estimate the power associated with each of the received bursts using the signal-level indicator implemented by the modem. This is a sort of fast AGC (automatic gain control), whose low-pass filter (digitally implemented) bandwidth is chosen to be narrow enough to filter out most of the noise and wide enough to track the shortest burst. The characteristic of such an estimator is given in fig. 5.15.

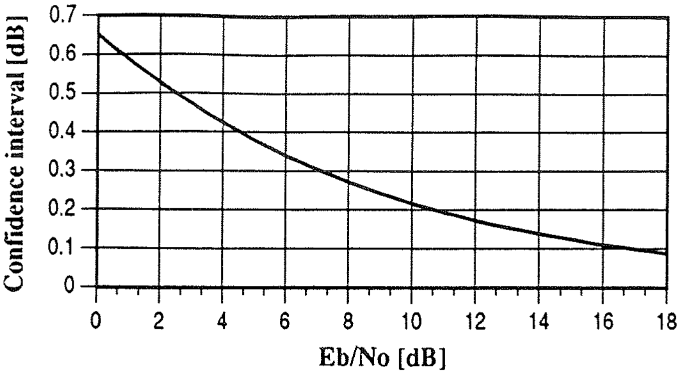


Fig. 5.15. Confidence interval of the measured signal amplitude at 99% level (QPSK). The one pole filter has a 32 symbol time constant.

In the following all the power levels are expressed in dB. In order that all the stations maintain the same IPDF at the satellite, each station compares the levels of the bursts sent by itself with the level of the reference burst sent by the master. The difference is used to modify the output power of the station's HPA. This is easily realised by modifying the modem's IF level according to a look-up table which takes into account a small non-linearity in the transmit chain. Within the up-power-control range each station can fully compensate the up-link fade level. The up-link residual attenuation due to out of range operation is compensated with adequate coding and bit rate. The up-power control range of each station depends on the station power margin. An interesting feature of the system is the freedom of sizing the stations according to the traffic intensity, the climatic conditions and the geographic position.

In order to keep its IPDF constant the master needs a reliable estimation of the up-link attenuation. The estimation is accomplished by comparing the level of the bursts transmitted by itself with a reference level measured in clear sky conditions: let P_{ru} be the up power reference level (clear sky), and P_{rd} the received signal reference level (clear sky). The total attenuation A_t is thus

$$A_t = (P_{cu} - P_{ru}) - (P_{cd} - P_{rd}) \qquad [\mathrm{dB}]$$

where P_{cu} and P_{cd} are the current transmitted and received powers respectively.

A_t is split into its up-link and down-link components using the long-term frequency scaling formula [24]. The ratio between the up and down attenuation, due to the on board antenna mispointing error, can be assumed proportional to the square of the relevant frequencies ratio:

$$A_{mu} - A_{md} = 2 \log_{10} (F_u / F_d) \qquad [\mathrm{dB}]$$

where A_{mu} and A_{md} are the up and down-link attenuations respectively.

The assumption of the same behaviour for the rain attenuation (in the K_a band) introduces an error of less than 0.5 dB over a range of 15 dB. This simplifies the problem because the two effects do not need to be distinguished.

An objection can be made concerning the application of the long-term frequency scaling formula to compute instantaneous values (short-term) of the attenuations ratio. In fact, the above ratio depends on rain type and temperature [26].

Experimental results in the K_a band (total attenuation range >5 dB) show that the use of the long term frequency scaling formula leads to a maximum error of 2dB (Fig. 5.16). Other measurements in the K_u band [27] show essentially the same behaviour of the attenuations ratio.

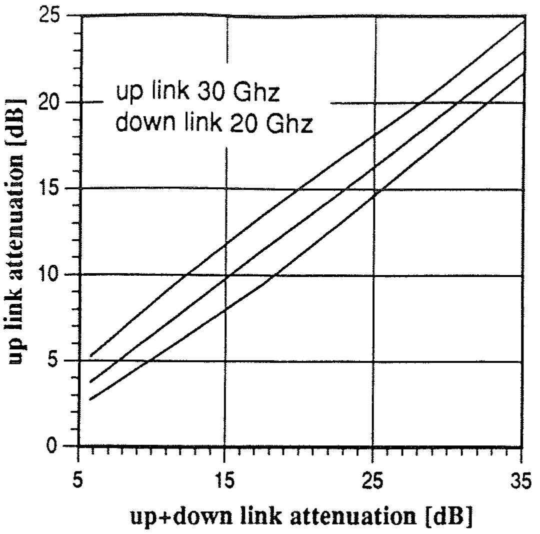


Fig. 5.16. Minimum, maximum and average up link attenuation versus total attenuation.

The error made by the master in transmitting the reference power level is reduced by a distributed correction mechanism. Each station sends to the master its estimation of the master reference power level, allowing a $\sqrt{N}$ reduction on the standard deviation of the measurement if the contributions can be assumed to be statistically independent.
At least one station is always available to assume the role of master, when the current master fading conditions increase over a certain threshold. The adopted master switch-over mechanism is fully transparent to all the other stations.

5.8 The link quality estimation and dissemination

Each sender station must know the signal to noise ratio available at the station to which its data is addressed, in order to choose the right transmission parameters (bit and coding rates) in such a way to ensure that data is received with the BER tolerances specified by the requested class of service. The parameter chosen to express the link conditions is the C/N_0 ratio. Denoting by *r* the bit rate in bit/s, the E_b/N_0 (bit energy to noise power density) ratio results

$$\frac{E_b}{N_o} = \frac{1}{r}\frac{C}{N_o} \qquad (1)$$

The estimation of the Eb/N_0 ratio is made by each station, on each burst arrival, by detecting the percentage of bits (Fig. 5.17) whose magnitude is less than a certain threshold (fraction of the average signal amplitude).

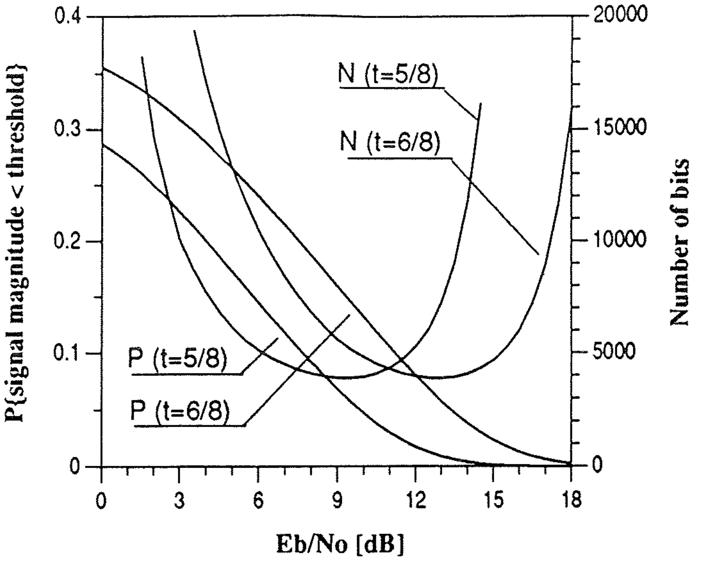


Fig. 5.17. Probability that the signal magnitude is less than the threshold t and number of bits for an Eb/No estimation with a confidence interval of 0.5 dB at 99% versus Eb/No.

Two different procedures are here shown to estimate the C/N$_0$ ratio over the transmission links, among all the sending to all the receiving stations.

a) *Direct method*

The C/N$_0$ value is sent directly by each receiving station to each sending station. The advantage of this method is that the maximum precision in the parameter estimation can be reached, while the disadvantage consists of the overhead introduced by the volume of control data requested. In fact, when a station falls in fade conditions, it must frequently send an update of its situation to all the stations sending data to it. Moreover, if filtering and/or prediction techniques are employed to better evaluate the C/N$_0$ ratio, each receiving station must process data relative to all the links active with the sending stations. In some cases it could be a big computing load.

b) *Indirect method*

It is supposed that each station broadcasts periodically the value of C/N$_0$ relative to data it is receiving from the master. The sending station is able to evaluate (analysing the received data) the two C/N$_0$ values, relative to the data sent by the master and the data sent by itself, respectively. It is also supposed the sending station knows the ratio between the up-link C/N$_0$ value (at the satellite transponder receiver) relative to data sent by the master and the same parameter relative to data sent by the itself, respectively. The parameter $z_{s\text{-}r}$ (i.e. the C/N$_0$ available at the receiving station when the sending station is transmitting) must be evaluated. Let us make the following notations:

ζ_{u_m} = up-link C/N$_0$ when the master is transmitting,

ζ_{u_s} = up-link C/N$_0$ when the sending station is transmitting,

$\zeta_{d_{mr}}$ = down-link C/N$_0$ at the receiving station, when the master is transmitting,

$\zeta_{d_{sr}}$ = down-link C/N$_0$ at the receiving station, when the sending station is transmitting,

$\zeta_{d_{ms}}$ = down-link C/N$_0$ at the sending station, when the master is transmitting,

$\zeta_{d_{ss}}$ = down-link C/N$_0$ at the sending station, when the sending station is transmitting,

$\zeta_{m\text{-}r}$ = C/N$_0$ available at the receiving station, when the master is transmitting,

$\zeta_{s\text{-}s}$ = C/N$_0$ available at the sending station, when the sending station itself is transmitting,

$\zeta_{m\text{-}s}$ = C/N$_0$ available at the sending station, when the master is transmitting.

Assuming the transponder TWT operates sufficiently backed-off, so that any carrier input level change be transferred linearly to the corresponding output level, we have

$$\frac{\zeta_{u_m}}{\zeta_{u_s}} = \frac{\zeta_{d_{mr}}}{\zeta_{d_{sr}}} = \frac{\zeta_{d_{ms}}}{\zeta_{d_{ss}}} = \alpha. \tag{2}$$

So

$$\zeta_{s\text{-}r} = \frac{\zeta_{u_s}\,\zeta_{d_{sr}}}{\zeta_{u_s} + \zeta_{d_{sr}}} = \frac{1}{\alpha}\,\frac{\zeta_{u_m}\,\zeta_{d_{mr}}}{\zeta_{u_m} + \zeta_{d_{mr}}} = \frac{1}{\alpha}\,\zeta_{m\text{-}r} \tag{3}$$

To evaluate α let us consider the ratio

$$\frac{\zeta_{m\text{-}s}}{\zeta_{s\text{-}s}} = \frac{\zeta_{u_m}\,\zeta_{d_{ms}}}{\zeta_{u_m} + \zeta_{d_{ms}}}\;\frac{\zeta_{u_s} + \zeta_{d_{ss}}}{\zeta_{u_s}\,\zeta_{d_{ss}}}. \tag{4}$$

Substituting in (4)

$$\zeta_{u_m} = \frac{\zeta_{d_{ms}}}{\zeta_{d_{ss}}}\,\zeta_{u_s},$$

got from (2), we obtain

$$\frac{\zeta_{m\text{-}s}}{\zeta_{s\text{-}s}} = \alpha. \tag{5}$$

If all the quantities are expressed in dB we have

$$\zeta_{s-r} = \zeta_{m-r} + \zeta_{s-s} - \zeta_{m-s}. \qquad [dB] \qquad (6)$$

With the following notations:

C_{s-s} = received carrier power level available at the sending station, when the sending station itself is transmitting,

C_{m-s} = received carrier power level available at the sending station, when the master is transmitting,

we can also write

$$\zeta_{s-r} = \zeta_{m-r} + C_{s-s} - C_{m-s}. \qquad [dB] \qquad (7)$$

The convenience to use the relationship (6) or (7) depends on which of the two quantities (C/N_0 and the carrier power level) can be evaluated with better accuracy.

The disadvantage of this method consists of the higher dispersion (bigger standard deviation σ) in the evaluation of the parameter ζ_{s-r}. In (7), the term $C_{s-s} - C_{m-s}$ represents the sending station up-link attenuation, that is not compensable with the up-power control mechanism.

In fig. 5.16 the number of bits to inspect, in order to get an E_b/N_0 with a confidence interval of 0.5 dB at the 99% level, is given for the signal magnitude thresholds of 5/8 and 6/8, respectively. The choice of the threshold depends on the link quality dissemination method employed. In case of direct method the range of E_b/N_0 is 7÷12 dB, so the best value of the threshold is 5/8. Using the indirect method the quality of the RB must be determined by all the stations, resulting in a wider range. In fact the RB is always sent at 2Mbit/s to allow a margin for the faded stations and C/N_0 is 6 dB higher. The resulting range of 7÷18 dB implies that the 6/8 threshold is chosen.

5.9 The data flow inside the FODA/IBEA system

Data are supposed to enter the FODA/IBEA system coming from a gateway connected to the Up and to the Down parts of the system via two dedicated lines. The gateway is able to communicate with the FODA/IBEA system via the GA-FO protocol [10]. Hereafter, this gateway will be called *GA-FO gateway*.

Both isochronous and anisochronous applications run on local area networks in some way interconnected among them. The GA-FO gateway receives data from the applications and sends them to the FODA/IBEA system. A virtual connection is supposed to be set up between the source and the destination GA-FO gateways before a stream application transmits data. Therefore, a GA-FO gateway supports as many virtual connections as the number of supported stream applications (max 255). Each stream application is assigned an application identifier corresponding to a virtual connection. The source and the destination GA-FO gateways are supposed to set up each virtual connection by exchanging information using datagram transmissions. Once the virtual circuit is set up, the data of a certain stream application can be transmitted by the system in the assigned transmission window. Each stream application is free to choose the length of its data packets on the basis of the required throughput; once chosen, the length must be the same for each packet.

As far as the datagram applications are concerned, each datagram packet includes the routing information. This is supposed to be contained in the LAN header on top of the data of each datagram packet. The LAN header is treated without any special protection with respect to the real data. In fact, it is useless to send the LAN header with higher protection because in case of corruption the packet must be discarded, whichever part (header or data) is corrupted.

The FODA/IBEA system is supposed to receive packets from the GA-FO gateway 2047 bytes long as maximum. It means that the GA-FO gateway is supposed to be able to break into packets of 2047 bytes longer packets generated by an application.

Data coming from the GA-FO gateway are enqueued to the Up process of the FODA/IBEA system into different queues according to the type of traffic (stream, bulk or interactive).
Indeed, *the stream queue is not unique* for all the data coming from all the active stream applications (i.e., which want to send data via satellite), but one stream queue is foreseen for each stream application. The use of a unique stream queue has, in fact, the following drawbacks.

a) *The incorrect behaviour of each user influences the behaviour of the other users.*
It means that the bandwidth required by an user is not guaranteed if another user does not respect the declared throughput.

b) *The jitter of each application influences the jitter of the other applications.*
An application with a high jitter may, occasionally, send a certain number of aggregated packets. When it happens, being the queue served in FIFO order, most of the bandwidth is used to serve the high jitter application. This induces bigger delays to the other applications.

c) *The maximum life-time of a stream packet cannot easily be limited.*
The problem arises to flush out too old packets of a certain application only. If the packets of all the stream applications are mixed in a unique queue, the flushing procedure results too laborious. The maximum number of outstanding packets in the queue of each stream application is a value declared in the GA-FO protocol when a new stream application comes up in the system. This number is, in general, different for each application, i.e. different stream applications may require different jitter restrictions.

Due to the previous reasons, stream data are enqueued per application in the FODA/IBEA system. The stream queues are served in FIFO order, according to the set-up time of each application. For each application an amount of data corresponding to the assigned throughput is sent in each frame.

On the FODA/IBEA DOWN process data is generally received from satellite in the form of packet fragments (one fragment may be a complete packet). Therefore, it is necessary to maintain queues of fragments for the reassembling of the packets. These queues are divided in *stream, interactive and bulk* types. There is one bulk and one interactive queue of fragments for every possible source station, and as many stream queues of fragments as the possible number of active applications (for every source station) is.

The reassembling of the *stream packets* is based on the *buffer identifier* and the *packet length* (stream packets from the same application have all the same length). In case a packet is not completely received (actual length minor than packet length) and a station has received a fragment of the new packet (which has a different buffer identifier), the previous incomplete packet is sent to the GA-FO gateway (marked as incomplete).

The reassembling of the *datagram packets* is based on the *buffer identifier* and the *fragment number*. If the packet is not yet completed and the first fragment of the new packet is received, the fragment chain of the previous packet is dropped.

Reassembled data packets are inserted in one of the three packet queues before being sent to the GA-FO gateway in order to respect the different traffic priorities (the highest for stream packets, the lowest for bulk packets).

5.10 The system parameters

Frame length	20 ms
FAS slot frequency	every 32 frames
FAS slot size	~0.3 ms
Bit rate to access the FAS slot	2 Mbit/s
Reference burst size	15 + (Number of stations * 5) bytes
Bit rate/code rate of the R.B.	2Mbit/s, 2/3 coded
Number of control slots per frame	2
Size of each control slot	~ 0.15 ms
Bit rate of each control slot	2Mbit/s
Modulation scheme	QPSK
Max number of simultaneously active stations	64
Stream request granularity	32-bit words per frame
Stream assignment granularity	32-bit words per frame
Datagram request granularity	16 32-bit words
Datagram assignment granularity	32-bit words
Max number of supported stream applications per station	64
Max length of the FODA/IBEA packet	2047 bytes
Length of the stream data packet (in output from the GA-FO gateway)	any (up to 2047 bytes) but fixed for all the packets of the same application
Burst Preamble	336 bits
Unique word	48 bits
Frame overhead	Reference Burst + Inter bursts guard times + Data Burst Overheads + Data Sub-burst overheads + control sub-bursts
Data burst overhead	preamble + UW + control sub-burst
Data Sub-Burst Overhead	Preamble depending on the symbol rate of the preceding DSB and the symbol rate of the present DSB + short UW (24 bits)
Inter frame gap time	60 µs
Inter-bursts Guard Times	depending on the UW window advance and the symbol rate of the two consecutive bursts
Control sub-burst	Minimum: 5 32-bit words = 160 bits
Master fault recovery	SUPPORTED
Supported symbol rates	0.5, 1, 2, 4 Msymbols/s, changeable on a sub-burst basis
Supported coding rates	1, 4/5, 2/3, 1/2, changeable on a sub-burst basis

TAB. 5.18. FODA/IBEA parameters

6. OLYMPUS-TDMA (O-TDMA) HARDWARE REQUIREMENTS

6.1 The data sub-burst (DSB) structure

The data sub-burst structure is shown in Fig. 6.1.

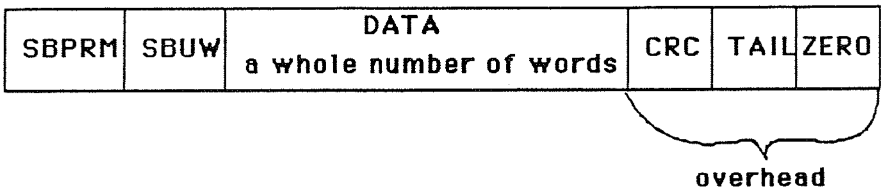


Fig. 6.1 The data sub-burst format

The DSB preamble (SBPRM) and the DSB unique word (SBUW) are required for all the DSBs, and their length depends on a number of factors, such as whether there is a symbol rate and/or code rate change at the start of the current DSB. These requirements depend on the clock and carrier tracking ability of the modem.
The SBPRM field length *depends on the symbol rate of the preceding DSB and on the symbol rate of the current DSB*, following the basic rule that DSBs within the same DB must be organised in an ascending bit rate order.

The SBUW structure is formed by the first half of the UW combinations:

P: UW, UW*
Q: UW, UW*

using the 12 bit binary sequence UW = 0 1 1 1 1 0 0 0 1 0 0 1 on each of the P and Q channels.

The SBUW field is 12 symbols long.

The overhead field (CRC+TAIL+ZERO) is transferred as a single null word to the modem interface board. It is necessary to supply the checksum and to flush the encoder.

6.2 Guard times between bursts

The guard times between bursts are determined from the modem quench pulse. There are two contributions: a) how long before the start of the burst does the quench occurs?, b) how much information in the receiver will be reset by the quench pulse?

The leading edge of the quench pulse occurs before the data burst preamble begins. This is due to the necessity to complete the quench before the preamble starts and the uncertainty in the preamble position. The quench pulse is 8 symbols of the coming burst rate long and it is required to complete before the preamble occurs. The uncertainty in the position of the start of the preamble is identical to the uncertainty in the position of the unique word. The quench is advanced from its optimum position by the amount the unique word window opens in advance with respect to the expected position of the UW. The grater the window advance (window length - window tail), the grater the quench advance is.
The guard time is dependent on the window advance and the symbol rate of the burst which has preceded the quench and is currently being processed by the hardware. In table 6.2 the guard

times between bursts for a default UW window (7, 4)[3] and a UW window (15, 3) are reported.

symbol rate (Msymbol/s)	0.5	1	2	4
window advance = 3 (7, 4)	88	44	22	11
window advance = 12 (15, 3)	160	80	40	20

TAB. 6.2

When the leading edge of the quench is received, all phase information in the demodulator is lost and the demodulator output is undefined. The number of symbols of data stored in the demodulator is not a simple function of the symbol rate (Tab. 6.3).

symbol rate (Msymbol/s)	0.5	1	2	4
delay in max symbol rate periods	68	54	22	16

TAB. 6.3

---

(3) (7,4) means: window length = 7 symbols, window tail = 4 ===> window advance = 3.

7. SYSTEM EVENT MEMORY

The event memory contains up to 512 events required by the hardware to define a transmit/receive frame. Each event is defined by a Time Code (18 bits) enabling frame lengths of up to 64 ms to be accommodated and a Function Code which sets control lines for the hardware.

Any two events must be at least 5 symbols apart.

7.1 On the UP controller

Reference to section 2.2.1.2 of [15].

FE	*(Frame End)*
field:	30 (**fe**)
operation:	resets the master station TFC.

BG	*(Burst Gate)*
field:	24÷29 (output level code), 31 (**bg**)
operation:	If bg is ON, the modem carrier is raised and output data are modulated. The FIFO begins to be emptied. If bg is OFF, the modem stops the transmissions. The output level code specifies the modem output power level in 0.5 dB steps from -20 dBm to 0 dBm.

7.2 On the DOWN controller

Reference to section 2.2.2.2 of [15].

WIND	*(WINDow event)*
field:	18÷21 (wlng), 31 (**wind**)
operation:	If wlng $\neq 0$, a window is set up whose length is put equal to the specified number of symbols. The symbol rate is the one of the expected burst preamble. If wlng = 0, the window is opened/closed according to the wind field. If wlng $\neq 0$, the wind field must be ON.

QUEN	*(Quench Modem)*
field:	22 (**quen**), 24÷26 (dcr), 27÷28 (dsr), 29÷30 (bcode)
operation:	it resets the modem (i.e. puts it in acquisition mode) prior to any expected burst reception. The bcode specifies the type of the expected burst. The symbol rate of the preamble and control sub-burst is specified in the dsr field. The coding rate of the control sub-burst is specified in the dcr field. The modulation scheme (B/QPSK) is specified in the Rx modem I/F Control Register. If bcode = reference, the interrupt EOF is caused.

TFP	*(Transmit Frame Pulse)*
field:	23 (**tfp**)
operation:	it resets the TFC. Because of the 5 symbols distance required between any two events, the TFP can be delayed by 1÷7 symbols. This delay is specified in the Rx modem I/F Control Register.

8. THE MARCONI SOFTWARE

The software of the satellite access scheme is split in two parts: one running on the Transmit Controller Unit and the other one running on the Receive Controller Unit. As already told, the two units are connected by a SCSI communication bus plus several more wires. Each of the units requires a control processor and the software running on this processor is termed a *kernel*. There are, therefore, two kernels: Tx (*Up process*) and Rx (*Down process*).

A kernel consists of a real time operating system (VME-EXEC) supporting user application tasks, device drivers and interrupt service routines (ISRs). The operating system is responsible for maintaining the tasks state (running, ready or blocked) and updating it as they interact. The scheduler is responsible for maintaining those tasks in the ready state or in order of their priority. The dispatcher ensures that when leaving the operating system, the highest priority ready task gains control of the processor.

The O-TDMA hardware has been delivered equipped with a software realising a F-TDMA(4) access scheme. In addition, the FODA/IBEA software is also installed. A special command is foreseen to select one of the two systems.

8.1 The MARCONI UP Kernel

The *UP kernel* consists of 10 tasks, drivers and interrupt service routines.
The tasks are shown in Tab. 8.1, which also indicates their functions and the files constituting each task.

TASK	FUNCTION
tini	*Initialisation.* It defines storage, communicates IPC, starts tasks, coordinates processes. It has the lowest priority to allow all the other tasks to enter their suspended state before it continues. It must send the relevant parameters to the Kernel Rx via the SCSI interface. It must suspend itself to allow the test or communication mode tasks complete control. When woken, it must distinguish the reason and take the appropriate actions.
tkbd	*Keyboard.* It responds to the console keyboard, performs resulting calculations, communicates with tprt. It receives each character from the keyboard and updates entries in the IPC data structure so that actions can be taken by the printing task (tprt) as a user response interaction. Calculations are performed which are a result of pressing a key.
tprt	*Printing.* It displays the currently selected menu or special screen, allowing "live"monitoring. It handles all output from Tx and Rx controllers to the VT100 terminal screen and continually updates menus showing selections and values, adjustment value, instructions and options, special keys, hardware alarms, system status and functions, time of the day. The information it prints is communicated to it via areas of memory updated by other tasks. It has heavy communication with tkbd because the user input is via that task and tprt must display the system response to the typed keys.
tpks	*Port K service.* It generates the *tp0s, tp1s and tp2s* tasks which keep the ISR pointers updated within the circular buffers. Each of the 3 tasks operates in exactly the same way, but using a different set of data specified by the user from the menu system (tprt and tkbd).

---

(4) Fixed-Time Division Multiple Access

tfev	*Frame event.* It responds to the SOFT ISR event and performs all frame related jobs, such as formatting transmission for the next frame. It has to build arrays for the control information associated with each burst. When this station is master, a reference burst is required, the data for which are entirely generated by the station.
talm	Alarm monitoring. It reads hardware status registers periodically to allow monitoring of fault conditions. It also checks that it has been sent an event from tfev to indicate that there are regular frames going on. If there are any errors, it updates an error reporting structure which tprt is able to display to the user. The timeout for this task is defined with a menu item, after which it wakes and checks the hardware errors in sequence. The error structure is updated for each one, but only the last error may be reported.
txmt **txmk** **txmp**	*TxM tests.* They allow the transmit modem testing in continuous mode. When the necessity arises, the regular tasks (tfev, tkbd, tprt and talm) are restarted by tini with an argument that makes them wait for an event. They, therefore, cease to function until this event is sent. Then, tini starts the test tasks dedicated to these continuous modem tests, sending them the menu parameters and also its own task ID. The test tasks allow a simple selection of a pre-defined test, allowing the user to perform one of a range of continuous modem tests.
tlpt	*Line printer.* It allows output of information to a line printer, if connected to the Tx controller printer port. The printer prints a message after a user specified period to indicate the time and to confirm that it is still "alive". Any other task may print the time of day as some pre-defined signal by sending an event to tlpt. Also, by constructing a message and placing a pointer to the start of the message in one of the words of the IPC structure, that message may be printed by sending another event to this task.

TAB. 8.1. MARCONI UP KERNEL

8.2 The MARCONI DOWN Kernel

The DOWN kernel consists of the tasks shown in Tab. 8.2, which also indicates their functions.

TASK	FUNCTION
rini	*Initialisation.* It defines storage, communicates IPC, starts tasks and coordinates processes. In a manner very similar to tini, this task must allocate storage for all IPC data and pack the addresses for each part into a message structure which is then distributed to all other tasks in the Rx kernel. Those tasks enter the suspended state at start-up, and rini starts them when the messages have been sent. It also performs initialisation of all hardware ready for orderly start-up of the system. After starting the other tasks, it enables interrupts so that each of the other tasks may function correctly. It is woken from the suspend state when some action is requested by the operator at the Tx menu system, this action being detected by the frame event task which receives the menu information as it is changed, from the SCSI interface with the Tx controller. Having performed the required action, the task loops back to the suspended state.

rfev	*Frame event.* It responds to the SORF ISR event and performs all the frame related jobs, such as analysing receptions from the last frame and loading events into the RxM to mark receptions during the next frame. It is responsible for loading events into the RxM off-line event memory ready for actioning during the next frame, informing the RxM data service ISR where to put received data in the next frame, examining the data from the last frame to enable pointers to be set for the Rx USI service task, monitoring of errors and status conditions, monitoring the CSF transmissions (when master) and initiating data transfers to the Tx controller. It is invoked at the very start of the receive frame by the event it receives the SORF ISR. The data recovery for the previous frame is complete and recovery for this frame is being performed by ISRs, which are using values supplied by this task during the previous frame.
rpks	*Port K service.* It generates *rp0s, rp1s* and *rp2s* tasks which use pointers and counts in the status area of the frame buffer blocks to update the RxU ISR for transfers of data to the ports. It is responsible for controlling the output data rate.
ralm	*Alarm monitoring.* It reads the hardware status registers periodically to allow monitoring of the fault conditions. It sleeps for a time specified by the user on the menu system , then checks each hardware status register for errors. It also checks that rfev has sent it an event to indicate that the hardware is functioning correctly by issuing a regular SORF interrupt. The errors are recorded in an error structure which is sent each frame to the Tx controller by the frame event *rfev* task.

TAB. 8.2. MARCONI DOWN Kernel

9. THE FODA/IBEA SOFTWARE.

The FODA/IBEA software realises the system described in chapter 5. It is mostly written in C language, the remaining part being written in Assembler Motorola 68030.
To better understand the behaviour of the tasks, the format and the use of some areas used by the tasks must be known. Therefore, references [10] and [13] are recommended.
For simplicity, we remind here that:

CCA	is the Channel Control Area. It is part of the DATAINF field present in a data burst.
ACB	is the Application Control Block. There is one ACB on the Up process for each stream application present in the system.
UGT	is the User Group Table. It describes groups of users.

9.1. Interrupt handlers

Hardware interrupts are used to synchronise software operations. Interrupts are initially (after reset) disabled. They are enabled by reading the status register.

9.1.1 On the UP controller

References to section 2.2.3 of [15].

SER	*(serial ports)*
board:	on board
level:	interrupt level 1
int. n.:	serial port
description:	it is triggered by incoming data or end of outcoming data on the serial ports.
action:	-it is handled by a serial ports driver embedded in the kernel. Used to deal with terminal communication.

LAN	*(LANCE Tx and Rx interrupts)*
board:	on board
level:	interrupt level 2
int.n.:	0x44
remarks:	The level of this interrupt is low because the LANCE is able to work in DMA mode.

Rx action:

- advances the buffer descriptor pointers for the LANCE chip;
- if control message, enqueues it to the *UPlh* task and exit;
- if datagram packet directed to inactive station, or stream packet with non-existent application identifier:
    - if in GATEWAY_DEBUG mode, a message to the *UPlh* task is sent;
    - if not, the packet is discarded.

- gets a buffer;
- links the buffer to the relevant queue (bulk, interactive, streams).

Tx action: - wakes up the Lsnd task upon packet transmission completion. Packets are transmitted one at a time, they are not enqueued to the LANCE.

COM *(Dn side to Up side communication)*
board: currently on board
level: interrupt level 3
int. n.: currently SCSI

description: it is triggered – once per frame – by the end of the Down side to Up side communication (currently a SCSI DMA operation).

action: -it is currently handled by a SCSI driver embedded in the kernel which wakes up the Downread task sleeping on a *read* system call.

SOTF *(Start Of Transmit Frame)*
board: TxM
level: interrupt level 4
int. n.: 0x83

description: if the station is master, this interrupt is triggered by the frame end (FE) event in the TxM event memory. If the station is slave, it is triggered by the transmit frame pulse (TFP) sent from the Down controller. Both the FE event and the TFP reset the transmit frame counter (TFC, clocked at 4.096 MHz).
The Down controller of a slave station sends the TFP at a time within the Rx frame defined by the MUW detection delayed by that station's receive/transmit frame time offset (RTOFS).

remarks: the SOTF ISR must reset the FIFO and must fill it with the current frame data. The interval between the SOTF time and the first burst gate (BG) event must keep into account the ISR latency, plus a convenient amount of FIFO filling. This interval can be roughly estimated in 60 µs. Therefore, the master must schedule the beginning of the RB at least 60 µs (240 TFC ticks) after SOF time. See EOF remarks.

action:
- checks that the Downread task has run in the meantime.
- clears the FIFO (to avoid errors propagation);
- fills the FIFO with the data to be sent.

FHF *(data FIFO Half Full)*
board: TxU
level: interrupt level 6
int. n.: 0x82
remarks: the transmit program is created by the Downread task.

action: - executes the transmit program (the FIFO is filled).

9.1.2 On the DOWN controller

References to section 2.2.4 of [15]

SORF *(Start Of Receive Frame)*
board: RxU
level: interrupt priority level 4
int. n.: 0x83
description: it is issued when the MUW is detected. This detection provokes the start of receive frame and the empty data FIFO is starting to be filled with the RB contents. The FIFO interrupt does not occur until 64 words have been loaded into the FIFO.
The SORF interrupt is also issued when the MUW detection window is closed and no UW is detected. The RxM issues a dummy signal with status indicating that the MUW was missed.

action: - sets up the on-board tick timer to generate the TIM interrupt.

EOF *(End Of Frame)*
board: RxU
level: 6
int. n.: 0x82 (same as FHF in section 3.1.3 pg. 60 of [15]]).

remarks: the Rx FIFO must be emptied when this interrupt occurs. This operation requires roughly 200 μs in the worst case, and no data must be received in the meanwhile. This requirement is satisfied if the sum of the inter-frame-gap (IFG) plus the preamble plus the master unique word (MUW) is 200 μs at least. The sum of the preamble and the MUW is 192 symbols, equivalent to 187 μs, for the preamble bit rate of 2.048 Mbit/s. This means that the IFG must be at least 13 μs long. For other reasons (see SOTF), the IFG must be set to 60 μs.

action: - the data FIFO is emptied by polling the FIFO EMPTY bit (DFEF).

OBE *(Output Buffer Empty)*
board: RxU
level: interrupt priority level 5
int. n.: 0x80

description: One of the ping-pong buffers relevant to one of the three serial interfaces is empty. The status word (see section 2.2.2.3 of [15]) tells which is the involved interface.
action: **TBD.** Relevant to the serial interfaces handling.

FHF *(data FIFO Half Full)*
board: RxU
level: interrupt priority level 6
int. n.: 0x82
remarks: data are received according to the relevant information contained in the control sub-burst.

action: - the data FIFO is emptied by moving data into memory;
- after the reception of each data burst, the Dnlh task is alerted to analyse the received data.

TIM *(TIMer Interrupt)*
board: on board
int. n.: tick timer
remarks: timer interrupt. The position of this interrupt in the frame must guarantee that at this time the RB must be already received.

reference: sets up in the SORF ISR.

action: - if in the area devoted to contain the last received reference burst there is no indication neither of MUW missed nor of RB received, the RB must be read out the FIFO in the correct area and the "RB received" flag must be set on;
- if master, the next RB to be transmitted is prepared;
- the DMA on the SCSI toward the UP controller is initialised in order to pass to the UP process the communication area;
- enqueues the last received RB to the queue of the last 14 received RBs;
- dequeues the oldest RB, set up the RxM event memory receive program, set ON a flag indicating RxM ready.

9.2 The FODA/IBEA UP Kernel

UPlh Up LAN Handler task: priority: 0x80 interrupt mask level: 0	It sleeps on the *uctl* (Up side control message) queue, waiting for a message. Messages are sent from tasks and from interrupt service routines. Most of the fade countermeasure logic is implemented in this task. The LAN interrupt handler sends a message to UPlh when it receives a control messages from the GA-FO gateway (typically birth or death of an application). The new bandwidth required by the station is then calculated and a request to the master is issued. When the master acknowledges the request, a redistribution of the space among the active applications is attempted. A similar action is taken when a change of the fade level is detected for this station or for other stations. The compression (if possible) of the stream applications is also handled.
Clrq Clear queues task: priority: 0xa0 interrupt mask level: 2	It checks the congestion status of the datagram queue and notifies it to the *UPlh* task. It releases the used buffers. It sleeps until it is woken up by the Downread task *Drea* (once every frame). The *Clrq* task handles the datagram traffic congestion countermeasure.
Lsnd LAN send task: priority: 0xb0 interrupt level mask: 0	It waits for messages to be sent to the LAN from other tasks. It performs all the necessary steps to send a packet and then it sleeps until it is woken up by the LAN interrupt handler when the packet transmission ends.
Drea Downread task: priority: 0xf8 interrupt level mask: 3	It prepares the event memory and the transmit program for the SOTF and for the FHF interrupt handlers.

Prnt Print message task: priority: 0xfa interrupt level mask: 0	It waits for messages sent by the other tasks to be printed on the terminal.

TAB. 9.1. FODA/IBEA UP Kernel

9.3 The FODA/IBEA DOWN Kernel

Dnlh Down LAN handler task	It is the main task on the down side. It analyses the received data bursts. The task is organised as an endless loop waiting for the BURST_RECEIVED event sent by the FHF interrupt routine. The received data burst is checked for formal validity, the stream and datagram requests, if present, are handled and the data packets are reassembled. Incomplete stream packets are anyway sent to the gateway, while incomplete datagram packets are thrown away.
Uwrt Up write task	It sends the UP process a data array (common to the UP and to the DOWN processes) by using the SCSI bus driver.
Prnt Print message task	It is a temporary solution for printing debug messages. It is supposed that this task will not be present in the final version of the FODA/IBEA software, at least not in the current form. It is implemented in order to print messages from the interrupt routines avoiding the interference of messages from different tasks.

TAB. 9.2. FODA/IBEA DOWN Kernel

10. FODA/IBEA TIMING CONSIDERATIONS

10.1 Guard times

An interval of time where the transmission is inhibited must be present between two consecutive bursts. Such an interval is called *guard time* (GT). It is the difference between the beginning of a burst nominal time and the end of the preceding burst nominal time. By convention we assume that all the bursts begin actually after the GT from the beginning of the time slot allocated to each station. The GT is the sum of three components: the QUENCH time, the unique word window length (UWWL) time and the time needed to flush out the data stored in the demodulator (demodulator delay).

QUENCH	It is used to reset the demodulator before the arrival of the next burst. The duration of the QUENCH pulse is 8 symbols of the coming burst rate.
UWWL	The RB UW window is closed one symbol after the nominal value. The granularity of the UW detection time is assumed one symbol of the coming burst rate. This will remain valid until a smaller granularity (one symbol of the maximum rate) will be demonstrated. At each RB miss the time basis of the missing station is shifted forward (delayed) of one symbol. It causes two facts: all the other stations receive the bursts of the missing station one symbol later; the missing station receives all the other bursts one symbol in advance. Assuming that two consecutive RBs can be lost before loosing the synchronism, and taking one symbol of margin, the UWWL of all the bursts (except the RB) is sized to 7 symbols, including the symbol which causes the detection. So the window is open 4 symbols in advance and closed 3 symbols after the nominal detection time.
Demodulator delay	The amount of time to flush out the data stored in the demodulator depends on the preceding burst rate, according to table 10.1. It is in the range from 16 to 68 maximum symbol rate periods.

Max GT = 8*8 + 7*4 + 68 = 160 [max. symbol rate periods] (40 bytes)
min GT = 8 + 7*4 + 16 = 52 [max. symbol rate periods] (13 bytes).

symbol rate	0	1	2	3
delay in max symbol rate periods	68	54	22	16

Tab. 10.1

In the stream request, in the stream allocation and in the datagram allocation times, the GT value is kept into account. In setting-up the transmission times the system software may not consider the max GT but some time may be saved doing more precise calculations. The saved time, if any, may be employed for transmission of more datagram. In order to do that, the preamble symbol rates of the present and of the preceding burst can be considered in evaluating the GT. In fact the last sub-burst of the preceding burst has symbol rate equal to or higher than the preamble symbol rate of the burst itself.

10.2 Time delays compensation

See par. 2.2.5.3 and 2.2.5.4 of the Marconi Software Manual [15].

10.3 Network synchronisation

The frame synchronism is given by the master station. The master frame counter (FC) goes from 0 up to the Frame End (FE) value. The RB is sent at a fixed epoch at the beginning of the frame. The master UW (MUW) detection event clears the FC of all the Rx controllers (including the master). The master does not need any synchronisation, because it gives the reference time. The offset between the Rx and the Tx times axes is set automatically in case of master. Each slave station must continuously measure its round trip time (RTT) and consequently adjust the position of its Tx frame time axis with respect to the Rx time axis. This is done positioning the transmit frame pulse (TFP) in the Rx event memory. The master cannot measure its RTT because it cannot set-up the TFP.

The default value of the RTT is used to get into the system initially.

Once a slave has got its Rx frame synchronised with the MUW, the initial TFP is positioned using the default value of the RTT. The error due to the satellite movements is in the interval ± 150 ms (600 max rate symbols). The first burst sent by the new station entering the network is centred in the first access slot (FAS). The FAS is dimensioned as large as twice the normal control slot (CS), in order to absorb the 150 ms error. The FAS has a fixed position at the end of the frame. It is present every 2^n frames, where n is set initially to 5. Looking at the *n* least significative bits of the frame number in the received RB, the new station knows when the FAS is present and accesses it in contention with other (possibly) coming-up stations.

In case of collision (time out on reception of its first burst) a retry is made and two are the possibilities: a) automatically, waiting a number of chances corresponding to the station physical address, b) manually (operator command).

The burst transmitted by the new entering station contains an 8 bit field specifying (bit 0-6) the 7 least significative bits of its Tx time. The bit 7 says if the FAS was used. If yes, the sending time is a well known value because the FAS has a fixed position inside the frame (just at the end of the frame). On receiving its first burst, sent in the FAS, a slave can immediately adjust the current RTT and then the TFP is correctly positioned. The RTT is then tracked continuously by the slave, computing the difference between the expected time and the detection time (in the UW status field) of the bursts sent by itself. The difference is expected to be of a couple of symbols as maximum, after the first burst correction has been made, so the 7 bit field is exuberant. The difference is computed modulo 128, so the seventh bit expresses the sign. This difference is used to adjust the current RTT.

Care must be taken in choosing the time interval between two consecutive updates securely bigger than the RTT, in order to avoid to operate more than one differential correction to the same measurement.

11. THE SYSTEM TESTING

Testing a complex communication system, as the FODA/IBEA system is, in a real environment poses a problem with regard to the characteristics and the reproducibility of the traffic feeding the system during the performance measurement procedure. A Multi-application Traffic Generator (MTG) has been developed, aimed at generating and recording a traffic of data packets on a Local Area Network (LAN) in controlled and reproducible conditions. The generated traffic is not distinguishable from the traffic generated by a number of real independent sources spread out over a LAN. Each of these traffic sources can generate *stream* or *datagram* traffic. MTG is able to produce a traffic that is the result of the activity of a number of schematically user-defined independent sources called *Traffic Generators* (TGs), whose behaviour is defined by a set of characteristics. The TG concept allows the modelling of a lot of traffic patterns, as it can be found in a real environment.

All the TGs are fully described in a common input file by the listing of their characteristics. They work concurrently during the run: the traffic generated by MTG is the sum of the traffics generated by each TG.

The MTG program consists of two distinct sections — called *controller* and *driver* respectively — interacting each other via a well-defined interface. The controller depends on the communication protocol with the FODA/IBEA system only, while the driver is tied to the LAN and it is independent of the communication protocol. This organisation gives some flexibility to the MTG system. In fact, if the FODA/IBEA system has to be tested over different LANs or MANs (Token Ring, FDDI, etc.), the same test conditions can be achieved with different types of network by just changing the driver section..

MTG is able to evaluate the performance of the communication system it is connected to in full duplex mode. Data generated by MTG cross the FODA/IBEA system and are looped back and received by MTG itself. Some characteristics of the communication system, such as packet delay, jitter, bit error rate (BER), etc. can be measured using this procedure.

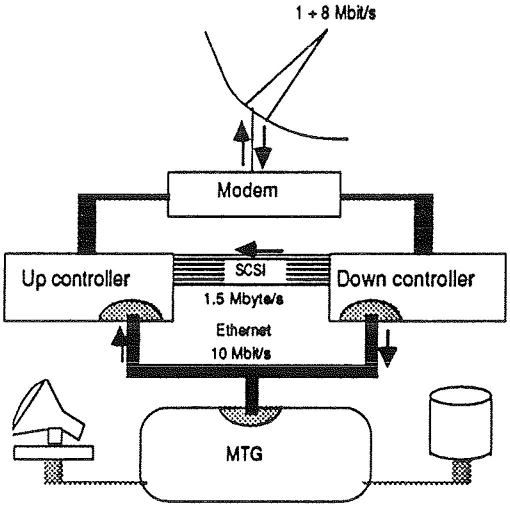


Figure 11.1. The configuration connecting the MTG with the FODA/IBEA system

A detailed description of the MTG can be found in [19, 20].

Appendix A

GLOSSARY

A

ACB	Application Control Block memory area
ATCB	Application Timer Control Block

B

BG	Burst Gate in TxM event memory

C

CCA	Channel Control Area memory area
Clrq	clear queues task
CSF	Control Sub-Frame

D

DFEF	output Data Fifo Empty Flag
DMA	Direct Memory Access
DN	(down) relative to reception from the satellite
Dnlh	down LAN handler task
Drea	down read task
dword	double word (32-bit word)

E

EOF	End Of Frame interrupt
EV	Event Memory

F

FAS	First Access Slot
FC	Frame Counter
FE	Frame End
FE	Frame End in TxM event memory
FHE	data FIFO Half Empty interrupt in RxSIF board
FHF	data FIFO Half Full interrupt in TxSIF board
FIFO	First In First Out

G

GA-FO	GAteway-FOda communication protocol
GT	Guard Time

I

IBF	Input Buffer Full interrupt
IFG	Inter-Frame Gap

IPC	Inter Process Communication
ISR	Interrupt Service Routine

L

LAN	Local Area Network
LANUP	LAN UP side interrupt
LCA	Logic Cell Array (chip)
Lsnd	LAN send task

M

MCCB	Master Channel Control Block
MUW	Master Unique Word

P

PDB	Prepare Data Burst interrupt
Prnt	print task

Q

QUEN	Quench Modem in RxM event memory

R

RB	Reference Burst
RBR	Reference Burst Received interrupt
RFC	Receive Frame Counter (the Rx event memory clock)
rfev	Receive controller Frame EVent
RTCB	Request Timer Control Block
RTT	Round Trip Time
RxM	Rx Modem interface board
RxU	Rx User serial interface board

S

SCB	Station Control Block
SCSI	Small Computer Serial Interface
SORF	Start Of Receive Frame interrupt
SOTF	Start Of Transmit Frame interrupt
STCB	Suffer Timer Control Block

T

TBD	to be defined
TBS	to be specified
TCB	Timer Control Block
TFC	Transmit Frame Counter (the Tx event memory clock)
tfev	Transmit controller Frame EVent
TFP	Transmit Frame Pulse
TxM	Tx Modem interface board
TxU	Tx User serial interface board

U

UP	relative to transmission towards the satellite
Uplh	up LAN handler task
USI	User Serial Interface board
Uwrt	(to) UP write task
UWSW	Unique Word Status Word (first Rx FIFO dword)
UWWL	Unique Word Window Length

W

WLNG	unique Word detection window LeNGth in RxM event memory

REFERENCES

[1] S.K. Barton (Signal processor LTD)
"Adaptive TDMA Systems for 20/30 GHz Fade Countermeasures", European Space Agency Contract Report; ESA contract number: 6652/86/NL/DG, Report Number R61142, April 1988.

[2] Timothy Pratt, Charles W. Bostian
"Satellite Communications", John Wiley & Sons

[3] "International Journal of Satellite Communications', chief editors: Barry G. Evans and Roger J. Colby, Dual Focused Edition: Fade countermeasures and multi carrier demodulators, Volume 6 Number 3, July-September 1988.

[4] A.S. Acampora
"A shared resource TDMA approach to increase the rain margin of 12/14 GHz satellite system", The BELL SYSYEM TECHNICAL JOURNAL, November 1979, pp. 2097-2111

[5] F. Carassa
"Adaptive methods to counteract rain attenuation effects in the 20/30 GHz band", North-Holland, Space Communication and Broadcasting 2, 1984, pp. 253-269

[6] G. Tartara, R. Carena
"Adaptive channel coding as a fade countermeasure in millimeter wave satellite communications", Satellite Integrated Communication Networks, North-Holland, edited by E. Del Re, P. Bartholome', P.P. Nuspl

[7] G. Tartara:
"Fade countermeasures in millimetre-wave satellite communications: a survey of methods and problems", proceedings of the Olympus Utilization International Conference, Vienna, Austria, 12-14 April 1989.

[8] Adams C.J., Burren J., Celandroni N., Ferro E., Hine M., Koudelka O., Waibel T.
"SATINE-II: an experiment in high speed wide area networking.
Part I: overview.
Part II:background and hardware development.
Part III: FODA-TDMA access scheme and software.
Part IV: tests and operations.",
proceedings of the European Teleinformatics Conference EUTECO '88 on Research into Networks and Distributed Applications, Vienna (A), April 20-22, 1988.

[9] N. Celandroni, E. Ferro, A. Marzoli:
"Fade detection for the FODA-TDMA access scheme", proceedings of the Olympus Utilization International Conference, Vienna, Austria, 12-14 April 1989, pp. 177-184.

[10] N. Celandroni, E. Ferro:
“Protocol between the FODA system and the outside environment. The GA-FO protocol”, CNUCE Report C91-21, 1991.

[11] R. Beltrame, N. Celandroni:
“The performance of the FODA access scheme: Theory and simulation results”, CNUCE Report C86-19.

[12] N.Celandroni, E. Ferro:
“FODA-TDMA satellite access scheme: description, implementation and environment simulation”, processing of the Tirrenia International Workshop on Digital Communications, meeting on <<Satellite Integrated Communication Networks>>, Tirrenia (Pisa), Italy, September 16-16 1987.

[13] N.Celandroni, E. Ferro:
“FODA/IBEA-TDMA. Satellite access scheme for mixed traffic at variable bit and coding rates. Implementation specifications.”, CNUCE Report C92-07.

[14] GEC-MARCONI Research Centre:
"Working specification for Olympus TDMA equipment", Issue 2.0, Y/212/9883, August 1990.

[15] GEC-MARCONI Research Centre:
"Olympus TDMA equipment. Software Manual. Issue 2", MTR 91/60A/, Y/212/10441, September 1991.

[16] GEC-MARCONI Research Centre:
"Olympus TDMA equipment. User Manual. Issue 2", MTR 91/60A, Y/212/10440, September 1991.

[17] GEC-MARCONI Research Centre:
"Olympus TDMA equipment. Transmit and receive controllers. Hardware manual. Issue 2.", MTR 91/60A, Y/212/10442, Sempember 1991.

[18] GEC-MARCONI Research Centre:
"Olympus TDMA equipment. Burst mode modem equipment manual", MTR 91/60A, Y/212/10443, Sempember 1991.

[19] N. Celandroni, I. Delic', E. Ferro, F. Potorti':
"The Multimedia Traffic Generator/Recorder. System description and user guide", CNUCE Report C90-21, August 1990.

[20] N. Celandroni, E. Ferro, F. Potorti':
"A tool for the performance evaluation of a satellite access scheme", proceedings of the ICCT'92 International Conference on Communication Technology", Tsinghua Campus, Beijing, China, September 16-18, 1992.

[21] Celandroni N."
Estimation of the Eb/No ratio using PSK quantized levels in an additive white gaussian noise (AWGN) environment", CNUCE Report C90-22, September 1990.

[22] Ferro E.
"A satellite network for good weather conditions and for high rain attenuation", proceedings of the SBT/IEEE International Telecommunications Symposium ITS' 90, Rio de Janeiro, Brazil, September 3-6, 1990.

[23] Celandroni N., Ferro E.
"The FODA-TDMA satellite access scheme: presentation, study of the system and results", IEEE Transaction on Communication, V. 39, N. 12, pp.1823-1831, December 1991.

[24] Shuzo Kato, Masahiro Morikura, Shuji Kubota, Hiroshi Kazama, Kiyoshi Enomoto:
"A TDMA satellite communication system for ISDN services -Offset QPSK burst modem coupled with high coding gain FEC-", proceedings of GLOBECOM '91, Phoenix (USA), November 1991.

[25] Celandroni N., Ferro E., Dossi L., Tartara G.
"User oriented satellite networks: studies on the utilization of transmission capacity in TDMA and TDMA/FDMA systems", European Transactions on Telecommunications, Vol. 2. N. 4, July-August 1990.

[26] Holt A.R., Mc. Guinness R., Evans B.G.
"Frequency scaling propagation parameters using dual-polarization radar results", Radio Sci., Vol. 19, pp. 222-230.

[27] Capsoni C., Matricciani E., Mauri M., Paraboni A.
Il "Frequency Scaling" - Programma Sirio - I principali risultati dell'esperimento di propagazione di onde elettromagnetiche a frequenza superiore ai 10 GHz. Vol II pp. 117-156. CNR-CSTS - Roma, 1983.

Marconi

No. MS 83

TECHBRIEF

GEC-MARCONI RESEARCH CENTRE

TDMA Controller and Burst Mode Modem for Satellite Communication

Introduction

This equipment, designed and built at the GEC-Marconi Research Centre, is being used to implement Time Division Multiple Access (TDMA) networks over the European Space Agency's Olympus and the DFS Kopernikus satellites. The equipment forms part of the user's earth station and consists of VMEbus based Transmit and Receive Controllers and a Burst Mode Modem. User access to the network is provided through the Controller which includes Ethernet, 64 kbit/s G.703, and 384/409.6 kbit/s RS 449 standard terrestrial interfaces. The earth station is interfaced to the modem at a channelized IF and is centered on either 70 MHz or 140 MHz.

The equipment incorporates a number of novel features since it is to be used to perform experiments on a wide variety of topics including:

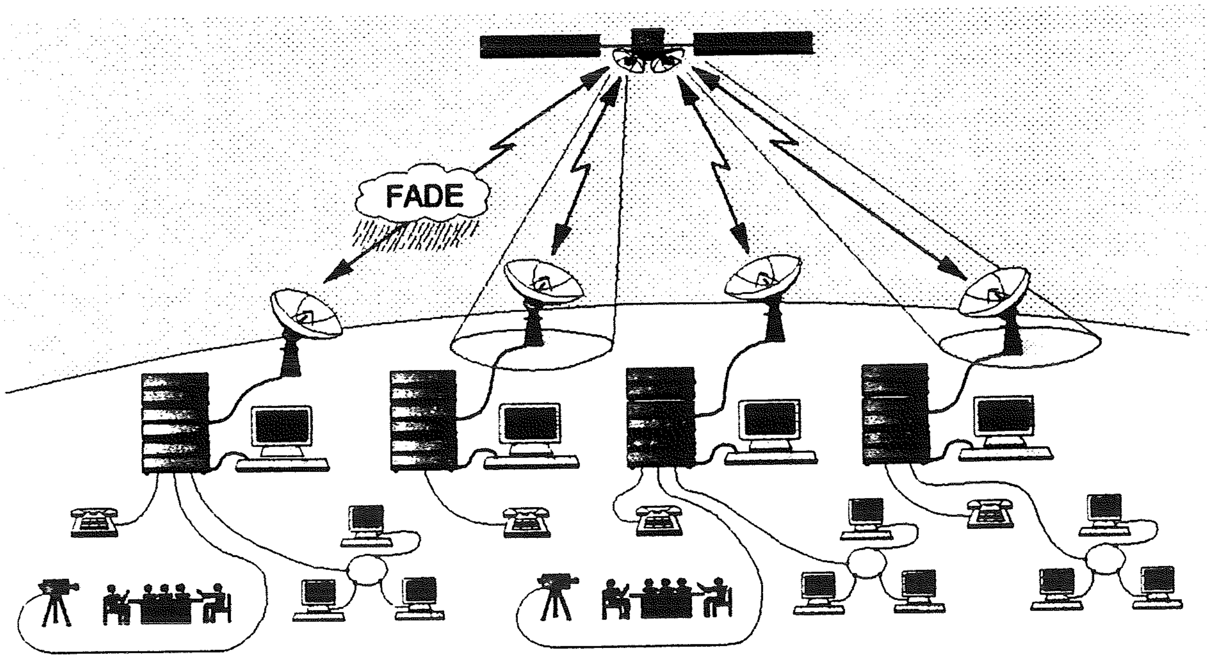
- Fade countermeasures in the Ku and Ka bands using transmission and code rate switching and band diversity.
- The management of mixed traffic types in a Demand Assigned (DA-TDMA) environment.
- Satellite Switched (SS-TDMA) operation using the Olympus specialized services payload.

The picture below shows the equipment being used with video conferencing, telephonic and local area network links with spot beams and fades.

Novel Features

To perform the range of experiments for which the equipment was designed the following special features have been incorporated:

- The parameters of the system are defined largely by software. This allows different frame lengths, frame structures, acquisition and capacity allocation algorithms, etc. to be developed.
- The Burst Mode Modem switches rapidly between 1.024, 2.048, 4.096 or 8.192 Mbit/s. This allows traffic data bursts to be composed of Data Sub-Bursts at different symbol rates.
- The Burst Mode Modem acquires rapidly and reliably at low signal to noise ratios. Typically the acquisition time is 160 symbols with a 99% probability at 8 kHz burst to burst offset, E_b/N_o = 7dB, 2.048 Mbit/s, QPSK.
- The Controller incorporates a punctured 1/2 rate convolutional codec based on the 133,171 code. This allows Data Sub-Bursts to be sent either uncoded or at 1/2, 2/3 or 4/5 rates.
- Extensive monitoring facilities are incorporated including received burst level, channel quality and cyclic redundancy checksums.
- The burst output level can be controlled over 20 dB in 0.5 dB steps.



Other Features

Other features of the Controller and Modem include:

- A VMEbus based Controller for easy expansion, enabling additional terrestrial interfaces to be either bought off the shelf or easily developed.
- Controller software structured into a number of prioritized tasks running under a real-time executive to allow ease of expansion.
- Terrestrial interfaces to G.703 at 64 kbit/s, RS 449 at 409.6 kbit/s or 384 kbit/s, and Ethernet.
- CRCs on Data Sub-Burst information for error detection.
- BPSK or QPSK operation.
- 40%√cosine roll-off filtering.
- Parallel 4-bit soft decision demodulated data.
- IF 52-88 MHz or 104-176 MHz in 22.5 kHz steps.

Baseline System Description

The equipment is supplied with software to implement a flexible, fixed assignment, TDMA system which demonstrates all aspects of the hardware. This baseline system has a frame consisting of:

- A Reference Burst for frame timeslot management and system timing.
- Acquisition/Housekeeping Bursts for Slave access and timing management.
- Traffic Data Bursts for transferring data between stations.

Each Traffic Data Burst consists of a Control Sub-Burst and a number of Data Sub-Bursts. The symbol rate and code rate of the Control Sub-Burst are defined in the Burst Time Plan transmitted in the Reference Burst, while the parameters of each Data Sub-Burst are transmitted in the Control Sub-Burst. Thus a station can use its timeslot allocation independently and enables each Data Sub-Burst to operate with the optimum burst parameters for the link and traffic type. The baseline software also allows all aspects of the system to be monitored and controlled via a simple VT 100 compatible terminal.

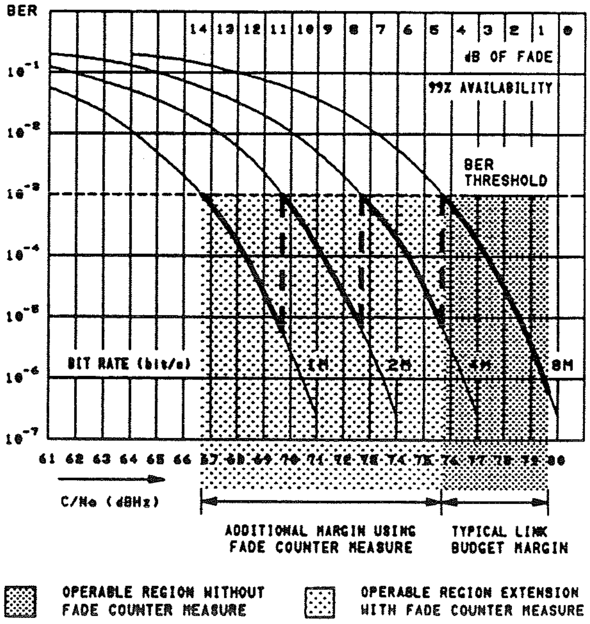
Applications and Developments

This equipment was designed to meet the specific requirements of a number of customers who are experimenting with different types of TDMA system. It is being used as a platform on which to develop and optimize algorithms for a variety of applications using an operational satellite. Although these demonstration systems will not necessarily be optimum, because of the generality of the design, they will be able to show which features are useful and how the various algorithms should be implemented.

The equipment is therefore an intermediate step towards a properly specified advanced TDMA product. Using the existing architecture, a commercial product could be housed in a single 19 inch 7U VME cardframe and configured for any one of several applications such as those listed below:

- Multi-Frequency TDMA.
- Satellite Switched TDMA.
- Demand Assigned TDMA.
- VSAT applications for Ku/Ka band.
- Specialized services for different user groups.
- Different terrestrial interfaces.

One way in which some of the flexibility of the equipment may be used is in a Ka band network where the transmission symbol rate can be reduced as the link fade severity increases. In the example shown below the link error rate is maintained to better than 10^{-3} with the result that the operating margin is extended from 4 dB to 14 dB. This increased margin could be used to reduce substantially the size of the earth station's antenna, its transmit power amplifier, and hence its overall cost.



Example of a System using a Fade Countermeasure

Contact

For further details please contact Mr. A.C. Baslington on extension 3119.

This document gives only a general description of the products and services and shall not form part of any contract. From time to time changes may be made in the product or services, or the conditions of supply.