Distribution and Broadcasting Satellites: European Projects and Problems

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It is becoming almost a common place to say that Europe has, in all fields of technology, more problems than projects : it is a continent divided into two parts politically and within that frame-work, the western part consists of a number of independent countries of different sizes, languages, cultures, political systems, degrees of industrialisation, etc.

In broadcasting technology these differences from the North American situation in particular, together with the still fundamentally different approach to the basic philosophy of broadcasting as a mass medium, lead to rather formidable problems in technical standardisation. Common broadcasting standards are increasingly important; because, more and more, the critical size of the market for the production of consumer products, is greater than any of the individual European countries.

1. Direct broadcasting satellites

The need for one single transmission standard for DBS is recognised by all parties involved in the process of standardisation in Europe: broadcasters, industry, telecommunications administration and governments.

So far, only one proposal for such a standard has been made: the C-MAC/packet system developed and agreed by the European Broadcasting Union.

The specification for this system was sent to the CCIR in 1983 and it has been described in detail via a number of publications; therefore I will only recall, in very general form, its objectives, its principal characteristics and its performance.

The aim was to devise a transmission system

- which used the capacity of the 27-MHz channels for DBS in the 12 GHz band in an optimal fashion without any infringement of the interference rules laid down in the WARC-BS-1977 for ITU Regions 1 and 3;

- which was to be the transmission standard adapted to the quality of the agreed digital 4:2:2 production standard;

- which, by fulfilling the different DBS requirements of all European countries, could be acceptable by each of them, and,

- which enabled receiver manufacturers to construct a single type of receiver which could be used all over the continent.

The main characteristics of this system can be described as follows:

- the structure of the complete signal continues to be based on the principles of a 625-line television signal with 2:1 interlacing
- the picture continues to be transmitted in analogue form
- the sound and all data services are transmitted in a digital form
- the analogue and digital components are arranged together, in variable proportions, in a time-division multiplex
- the time multiplexing of both the analogue and the digital components is effected at radio-frequency (C-type modulation)
- the luminance and colour-difference signals are themselves transmitted in TDM technique (MAC); they are frequency modulated as indicated in the Final Acts of the WARC-BS-1977
- the digital elements are modulated according to a four-state phase-shift keying modulation system (2-4 PSK) and arranged in packets of fixed lengths.

Having set out the reasons for using the name C-MAC/packet we can now quickly glance at some of its parameters and applications.

Fig. 1 shows the structure of one 64-μs scanning line.

This structure is based on a clock frequency of 20.25 MHz, this being chosen mainly for two reasons :

First, the inherent quality of the broadcast transmission standard is matched to that of the world-wide digital studio production standard, recommended by the CCIR.

If we compress, by the factors 3:2 and 3:1, the luminance and colour-difference signals with their respective sampling frequencies of 13.5 and 6.75 MHz we arrive at the figure of 20.25 MHz.

Secondly, for the digital components, a bit-rate of 20.25 Mbit/s is close to the capacity limit of the 27-MHz satellite channel when four-state phase-shift keying is used.

Given these conditions, each line contains a total of 1296 clock periods which, leaving aside those periods reserved for transitions between service components and for auxiliary purposes, are used in normal operations for the transmission of :

- a digital burst of 203 bits; 195 of these carry useful information, this corresponding to a mean bit-rate of about 3 Mbit/s;
- in turn, the analogue colour-difference components (350 clock periods) and the luminance component (699 clock periods).

Now let us have a look at the way in which the 625 line periods are organised in a full frame period of 40 ms. Fig. 2 shows the structure for the case under consideration. I should stress that the intervals allocated to each element have the values shown here and in the preceding diagram only in the case of so called "normal video conditions"; the intervals can be modified in both the horizontal sense (length of a component on the line) and in the vertical sense (number of lines used for that component within each frame). These intervals are governed by time-multiplex control data which are transmitted in the special data burst which occupies the whole of line 625. In particular, it is possible to lengthen the digital burst to the point where full-channel data are transmitted or, alternatively, to shorten it with a view, for example, to altering the aspect ratio of the picture.

In this configuration the data area contains 162 packets, starting in line 1 and ending in line 624. I shall come back later to this feature.

Synchronisation for the system is entirely digital. It is achieved by recognition, either separately or together, of a line synchronisation word of 7 bits and a frame synchronisation word of 64 bits inserted in line 625.

The principles of the MAC video coding system have been described in various publications; it has been developed largely in the UK's IBA at Crawley Court (UK). The EBU specification adheres to the original general principles, but it does incorporate several refinements.

As we have already seen, the MAC system is designed to transmit a quality corresponding to the future digital studio standard, i.e maximum bandwidths of about 6 MHz for the luminance signal and 3 MHz for the U and V colour difference signals.

The luminance signal is time-compressed on a line-by-line basis, in the ratio 3:2, and the bandwidth it occupies in the transmission channel is therefore increased in the same proportion. The compression is achieved by digitally sampling the signal which then loads a line store: this is read out at a higher frequency than the input and the signal is then restored to analogue form.

The colour-difference signals are subjected to time-compression of similar form, but this time the compression ratio is 3:1; the colour-difference bandwidth therefore remains equal to one-half of that of the luminance, as in the 4:2:2 digital standard.

The luminance and colour-difference signals are then arranged side-by-side in a single television line and are thus transmitted as a time-multiplex. The result is that the cross-colour and cross-luminance effects inherent to the PAL, SECAM and NTSC systems are eliminated. The final bandwidth of the MAC signals is 1.5 times that of the luminance signal at the picture source.

The colour-difference signals are transmitted alternately on successive lines; in other words, it is a line-sequential system. In this way the horizontal and vertical resolutions are approximately matched for the luminance and colour-difference information, but vertical pre-filtering is used to reduce the visibility of vertical aliasing to an acceptable level for the colour-difference signals.

Summarising, it may be said that the MAC system is a time-multiplex of time-compressed luminance and line-sequential colour-difference signals. Its principal advantages are an improvement in quality, resulting from the elimination of cross-colour and cross-luminance and the increase in component bandwidths, together with improved RF performance, largely because of the noise characteristics of FM, and its great flexibility as regards future enhancements.

Packet multiplexing of the digital signals for sound and data has been developed very largely by the CCETT laboratories at Rennes (France). The bit-stream of such a signal is made up of packets of fixed length.

Fig.3 shows the packet structure.

We recognise first, in the header: the address, a continuity index and a protection suffix and thereafter, the useful data area consisting of one packet-type (PT) byte which is used for sound services only and then 90 bytes for the sound services.

As we have seen already, in normal operation a total of 162 packets are transmitted in each 625-line digital frame.

The corresponding capacity of just over 3 Mbit/s can be used in any required manner, as and when appropriate. In particular, the television picture can be accompanied by the following sound components, each based on a 32 kHz sampling frequency (which permits an audio bandwidth of 15 kHz):

- either 4 sound signals with uniform coding and second-level error protection

- or 6 sound signals either with uniform coding and first-level error protection or with 14-10 near-instantaneous companded coding and second-level error protection

- or 8 sound signals with 14-10 near-instantaneous companded coding and first level error protection.

In each case a number of packets is left open for other uses. One of these is the identification of services. In fact, the multiplicity of services or service components which can be broadcast simultaneously in a single channel, either in the form of components of the time-division multiplex, or within the packet multiplex, requires the provision of an identification system to help users gain rapid access to the wanted service. This service-identification system must therefore offer:

- a readily-obtained list of available services;
- a means for automatically configuring the receiver and its decoders to suit the choice made by the user;
- a rapid indication of which service is being received.

These requirements have resulted in the development of a very elaborate system which I cannot describe in detail here. Let me just mention the data which are broadcast as a function of the selected transmission mode.

First of all we have seen that the whole of line 625 is reserved for a special data burst which, in addition to providing frame synchronisation, contains mainly information concerning :

- date and time
- satellite channel
- TDM configuration and details of the TDM multiplex itself.

Secondly, there is one dedicated digital channel, made up of all the packets bearing the address "0". It is reserved for the identification of the services carried in the packet multiplex. The coding structure is that recommended in CCITT Recommendation S.62 for teletex control. The transmitted information includes coded indications and also clear-language text, of variable length, which may be displayed on the television receiver screen or on a special display device. These include all the information needed by the public concerning the services and the programmes provided at a given moment in time by the operators of the system.

For a typical example in which the channel carries a television programme with original sound, three commentary sound signals and subtitles in three different languages, together with two radio services and four different teletext services, the bit-rate needed in the dedicated channel is of the order of 12kbit/s or 16 packets/s.

Thirdly, the information transmitted at the level of one digital service channel is concerned only with a service or service component and it is carried in the same digital channel as the service itself i.e., it uses packets bearing the same address as the service. These interpretation blocks (BI in the Fig.) normally have a length of one packet and the main information coded in them enables, amongst other things, the receiver to recognize the type of sound signal transmitted e.g. mono or stereo, type of coding and error correction, etc.

The system so far described is much better suited than NTSC, PAL or SECAM for television services where conditional access is required such as "Pay-TV" or "Subscription-TV". EBU studies in this field are in hand. They foresee the use of PRBS (pseudo-random binary sequence) generators for component rotation of the vision signal and digital scrambling of the sound and data signals. The optimum means of distribution of the key information for the PRBS generators is still under discussion, but one possibility is the transmission, over-air, of encrypted keys. The system must, of course, have some means of discriminating individual users, and a number of possibilities are being discussed for user access systems, such as the smart card, card and PIN system and over-air addressing. These systems essentially decrypt the encrypted key information. The question of whether all services should be scrambled, with some having a freely available key, is still to be decided.

Finally, some remarks about the performance of the system. We have already seen its great flexibility and the amount of headroom it leaves for future developments. The system indeed makes optimal use of the frequency spectrum attributed to satellite broadcasting in Europe. In a more specific sense, technical performance, which has been verified experimentally, is evidently one of the principal factors determining the choice of a new system.

For the picture, the MAC system eliminates cross-colour and cross-luminance effects, leads to appreciable increases in component bandwidths and improves the RF performance. Subjective evaluations have shown that the final quality is barely 0.1 grade (in the 5-grade quality scale) below that of the 4:2:2 digital studio standard where screens of conventional size are used.

As far as the basic sound quality under normal reception conditions is concerned, listening tests have shown that all of the forms of coding mentioned gives high quality within the dynamic range suitable for domestic listening conditions. No noise is audible on normal programme material originated from high-quality sources, although programme-modulated noise is perceptible with companded coding on very critical passages such as pure sine-waves.

The failure characteristic takes on a different form for the analogue components, for which the quality falls off gradually, and for the digital components, for which the service remains excellent down to a certain limit beyond which the degradation rapidly becomes severe.

In the MAC system, the colour-difference signals are not carried on a sub-carrier, and hence the noise power per unit bandwidth is less than in the case of composite PAL or SECAM signals; it is therefore to be expected that the failure characteristic will fall off more gradually. This has indeed been confirmed in many subjective tests conducted by the EBU. The first threshold effects (luminance spikes on the picture) were observed at C/N ratios of between 8 and 10 dB. The first audible clicks on the sound appeared at a C/N ratio of about 8 dB.

It must be stressed that, although these figures correspond to a perceptible impairment, the quality would still not be unwatchable or unlistenable. If we define the service failure point as lying halfway between quality grades "poor" and "bad", failure for a television service occurs between about 2 and 3 dB for the picture, i.e about 2 dB below the figure for a PAL or SECAM picture, and between about 3 and 4.5 dB for the sound depending on the type of coding and error correction.

In other words, the use of the C-MAC/packet system could mean considerably larger coverage areas than those obtainable with the reference system used at the WARC-BS in 1977.

As regards interference, subjective tests have also shown that the C-MAC/packet system satisfies the conditions imposed by the WARC-BS 1977 relating to protection ratios.

We can conclude that the C-MAC/packets system is more than just another television broadcasting system such as NTSC, PAL or SECAM. Its introduction may well open up a new era in broadcasting. In the past each broadcast channel, used in any of the frequency bands allocated to the broadcasting service, has generally been used for a single service, e.g. for a radio programme or a television programme.

The C-MAC/packet system brings with it the complete abandonment of this one-to-one relationship between channels and services. It is designed to provide for the variable and evolutionary broadcast transmission of a group of services within the limits of a channel which is that defined for satellite broadcasting by the WARC-BS-1977.

The composition of that group of services may vary from country to country or, more precisely, from transmitter to transmitter and, for each transmission, from one period of time to another.

One may be forgiven for wondering whether this flexibility is disquieting to those who are responsible for the media policy in some European countries. However, the broadcasters in the EBU have concluded that this system, devised collectively by a team of engineers and scientists from many countries, constitutes an optimal broadcasting system. It is ideally adapted for 12 GHz satellite broadcasting and, incidently, we believe its signals can be distributed over many kinds of cable networks without loss of quality. Its performance is excellent as far as reliability, quality and ruggedness are concerned. It lends itself to user-friendly hardware and it is future-oriented in that it can be tailored to all foreseeable applications and stands us in good stead for whatever the imagination of future engineers may bring. Although it may be ranged amongst the most sophisticated consumer products offered to the public, we are convinced that hardware cost will be reasonable. With this last point in mind, and considering the fact that the first DBS services may well start in Europe not later than two years from now, we feel that it should become a recognized European standard without further delay.

The question arises, why this is not yet the case. As part of their analysis of the question the governments of France, the United Kingdom and the Federal Republic of Germany have formed a number of working groups in order to investigate what has been termed "questions which need further examination" with a view to convening a European governmental conference which is to take a decision in the matter.

We are not aware of any official statement as far as composition, mandate, time-scale, or any results of work of these groups are concerned.

The United Kingdom government has recently stated in Parliament, that they are committed to the C-MAC/packet system, but the official attitude of the two other governments was still unknown at the time of writing this text.

The two main obstacles to the final adoption of this proposal by governmental authorities seem to be:

a) receiver cost predictions
b) the compatibility of the system with existing and planned cable systems.

Both questions have been studied extensively within the framework of the EBU activities and both questions have found - in our opinion - satisfactory answers. We are left therefore to conclude, that any remaining objections to standardise the system are more of a political nature than of a technical nature.

To understand this better, I shall briefly refer to the European situation with regard to cable distribution of television and sound broadcasting programmes.

2. Cable distribution

The development of cable distribution systems in Europe has followed a very different pattern from that in the USA. In the beginning its main purpose was to improve the reception quality of the national television programme or programmes in shadow areas, and then also to provide signals for programmes from neighbouring countries in border regions where the field-strength was too weak to provide a satisfactory picture by means of an antenna of reasonable size. The latter type of cable system can be found mainly in the smaller countries of Europe which have many neighbours: Belgium, the Netherlands, Switzerland, Austria. Thus, for example, about 85% of the Belgian households are now connected to extensive cable networks providing them with up to 16 programmes, 12 of which are originated in other countries.

However, until recently, there was no question of authorising the cable operators to produce their own programmes; they remained simply distributors of existing programmes that could be picked up somewhere within the limits of the national territory.

With the advent of distribution satellites, a radical change in media policy took place in the larger countries. In particular in France, Germany and the United Kingdom plans began to emerge to gradually cover these countries with a national cable distribution system, by using either traditional coaxial cable techniques or glass-fibre networks, or a combination of them. Satellites, either those developed by the European Space Agency and exploited by the Eutelsat organisation (the ECS-system), or national satellites, or even Intelsat-controlled satellites could then link, at least for a rather long initial period, the "islands" of cabled towns together. These cable systems can thus be fed, from the beginning, not only by local or national programme providers, but also by commercial programme originators in any European country, or indeed - why not - extra-European country.

It is understandable that governments who have developed plans of this sort, may find it difficult to see a place for DBS in this scenario. If, by one future means or another, the population has already, via cable and distribution satellites, the choice between, say, 30 television and a similar number of radio programmes, why then undertake the additional effort of developing and financing a DBS system which can, after all, do nothing more than add a maximum of five further television programmes ?

Of course, this view is not shared by everybody, and indeed the argument that the future rather lies in DBS, and that therefore cable systems should help to develop DBS and not the other way round, has its proponents.

According to this perspective, DBS and cable distribution are seen to be complementary, not as an alternative, and thus the EBU has engaged in studies to use the proposed DBS standard for cable networks.

Such studies are being carried out primarily in France and Germany; they would enable a complete C-MAC/packet signal to be carried without loss of capacity or quality in a cable system (i.e in a CATV system as well as in a master antenna configuration). Fig. 4 shows the basic philosophy of these possibilities. Experiments show that the bandwidth requirement of 27 MHz for DBS can be reduced to suit any type of cable system, for example :

- to 7 MHz by using a B-MAC/packet system with a quaternary (4-level) digital signal (where, however a certain loss of resolution must be accepted), or

- to between 10 and 14 MHz with vestigial-sideband amplitude modulation for vision and duobinary modulation for sound and data.

3. Satellite projects

In the field of satellites belonging to the fixed-satellite services and foreseen for, or capable of, transmitting broadcasting programmes, the first operational system will be the ECS-system of Eutelsat. Figs. 5 and 6 and 7 show the attribution of TV/downlinks to various European countries and to the EBU within the three spot-beams and the Eurobeam of that system. Together with similar national satellite projects in France, Germany, the United Kingdom and the Scandinavian countries, there will be, towards the end of the 1980s, a large number of facilities capable of feeding cable-systems all over Europe. But it seems doubtful, whether these channels will all be used by then, or indeed later.

As far as broadcasting-satellite services (DBS) are concerned, most of the projects so far known have been developed primarily in order to promote the European space and telecommunications industry. In chronological order, these projects, all of which, with one exception, are based on the characteristics of the WARC-BS-1977 Plan, are:

- TDF-1 and TV-SAT, a common project financed by the French and German governments respectively, to be launched at the end of 1985. Both have three WARC-channels. One of the TV-SAT channels will use purely a digital sound broadcasting system developed in Germany (16 stereophonic programmes), and which is not related to the C-MAC/packet proposal. It may be mentioned however that the latter could provide an almost identical facility. The remaining five channels will probably transmit television programmes and it is to be feared that they will use SECAM and PAL, possibly with analogue sound (two monophonic channels or one stereophonic channel). These transmissions have, however, been qualified as experimental or pre-operational.

- UNISAT of the United Kingdom, to be launched 1986/87, with two television channels, possibly one of which will be in a conditional-access mode. This may well be the first operational DBS-system in Europe, and, as already stated, it is likely to use the C-MAC/packet system.

- L-SAT (Olympus) a large multi-purpose platform to be launched by the European Space Agency (ESA) in 1986/87. It will use an orientable downlink antenna which will enable any part of Europe and parts of North Africa and the Middle East to be covered, and requires therefore authorisation from the relevant signatories of WARC-BS-1977. One of the two television channels will be used for Italian coverage and the other, most probably, by Members of the EBU who wish to carry on, for three years initially, with programme experiments for a pan-European service. Because of the need for a large number of sound channels (and, possibly, sub-titling facilities) for such a programme, the PAL or SECAM transmission systems (with analogue sound) are totally unsuitable for this experiment.

- TELE-X, a Swedish multiple-purpose experimental project, with the participation of certain other Nordic countries, to be launched 1987/88. There are to be three TV transponders, two of which can be used to cover, in accordance with the WARC-BS-1977 Plan, the Scandinavian area.

There are certainly more plans at a less advanced stage of planning or construction.

We can however, already conclude, that the absence of a Europe-wide agreement amongst governments, if continued, on a common transmission standard, will be a serious obstacle to the development of DBS in Europe and that thereby European industry is in the process of losing a unique opportunity to regain leadership in the field of modern consumer product technology.

Thus at the end of my talk, I can only emphasize, with some regret, what I said at the beginning:

> Europe has more problems than projects, and whilst some of the projects may look promising, their realisation is often hampered by problems generated by the Europeans themselves.

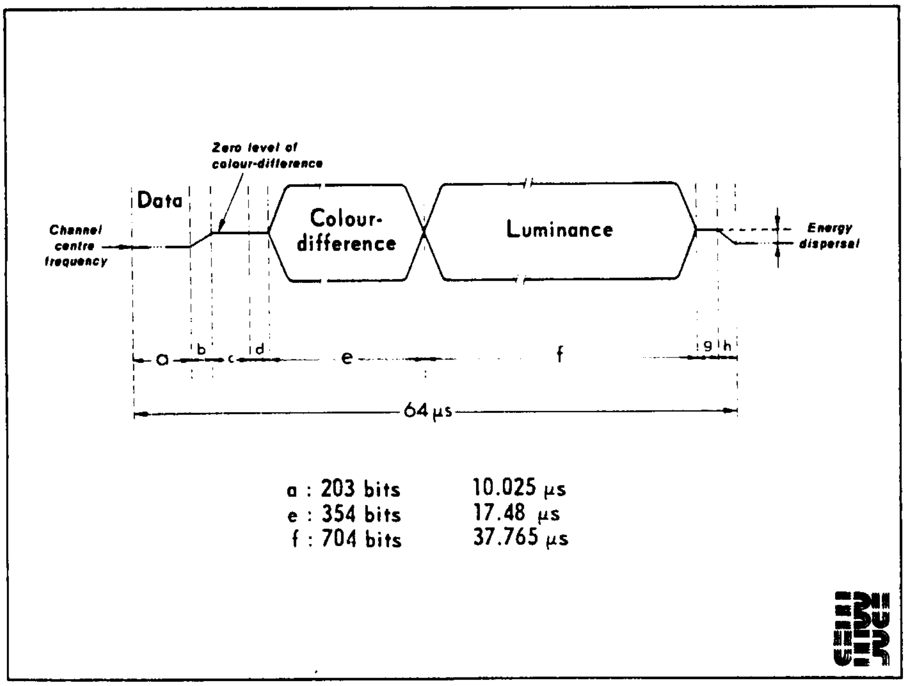
Zero level of colour-difference
Data
Channel centre frequency
Colour-difference
Luminance
Energy dispersal
a
b
c
d
e
f
g
h
64 μs
a : 203 bits 10.025 μs
e : 354 bits 17.48 μs
f : 704 bits 37.765 μs

Fig. 1.

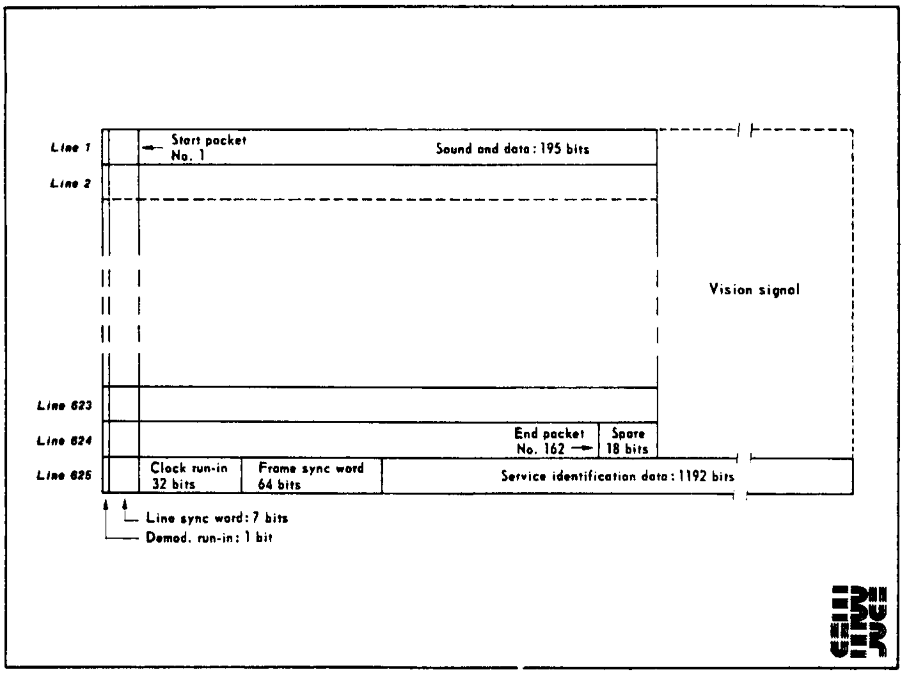
Line 1
Line 2
Line 623
Line 624
Line 625
Start packet No. 1
Sound and data: 195 bits
Vision signal
End packet No. 162
Spare 18 bits
Clock run-in 32 bits
Frame sync word 64 bits
Service identification data: 1192 bits
Line sync word: 7 bits
Demod. run-in: 1 bit

Fig. 2.

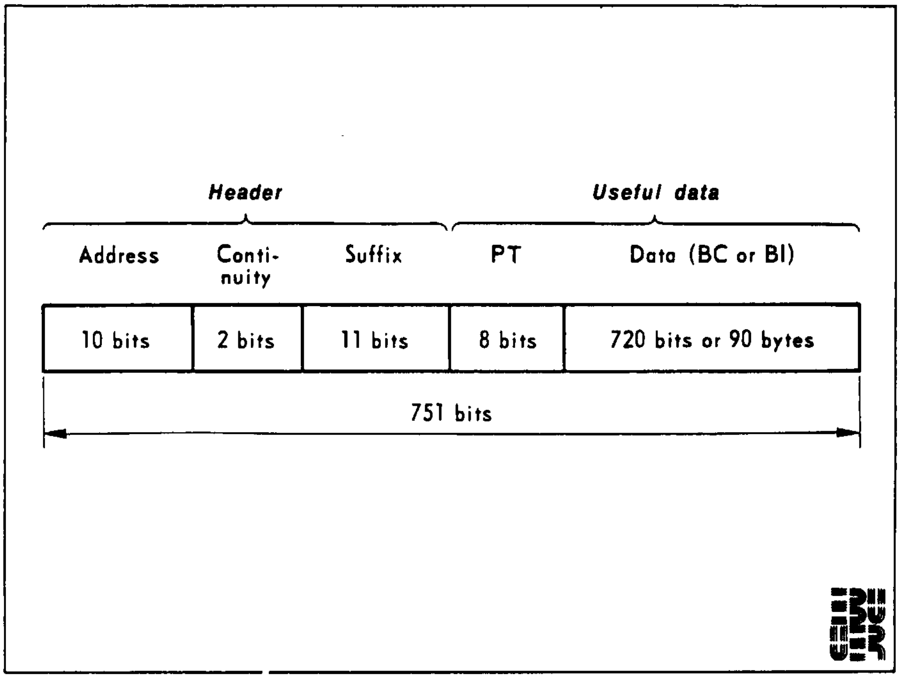
Header
Useful data
Address
Conti-nuity
Suffix
PT
Data (BC or BI)
10 bits
2 bits
11 bits
8 bits
720 bits or 90 bytes
751 bits

Fig. 3.

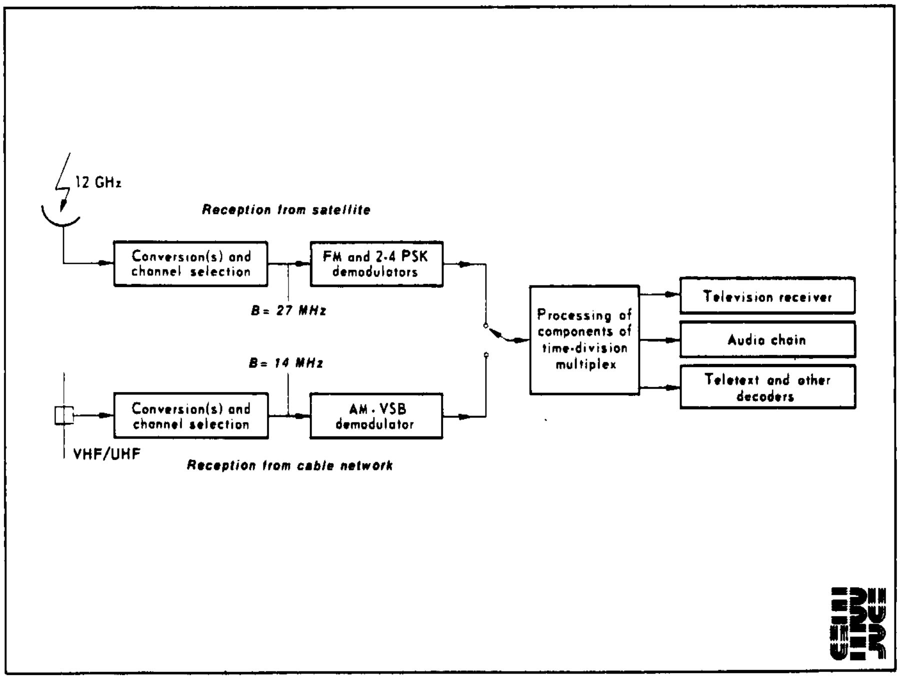
12 GHz
Reception from satellite
Conversion(s) and channel selection
FM and 2-4 PSK demodulators
B = 27 MHz
B = 14 MHz
Conversion(s) and channel selection
AM - VSB demodulator
VHF/UHF
Reception from cable network
Processing of components of time-division multiplex
Television receiver
Audio chain
Teletext and other decoders

Fig. 4.

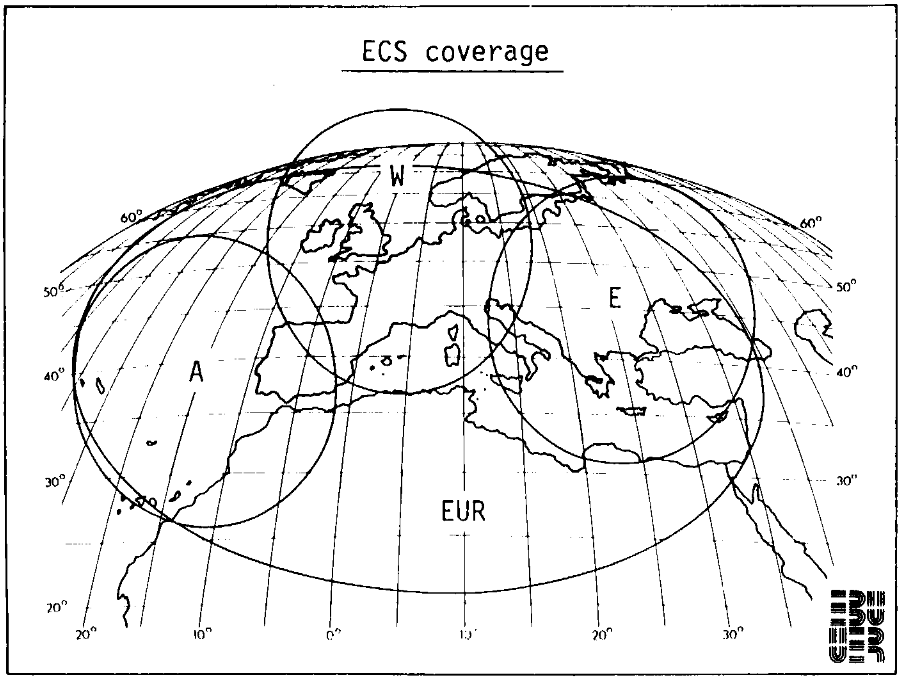
ECS coverage
W
E
A
EUR
60°
50°
40°
30°
20°
20°
10°
0°
20°
30°

Fig. 5.

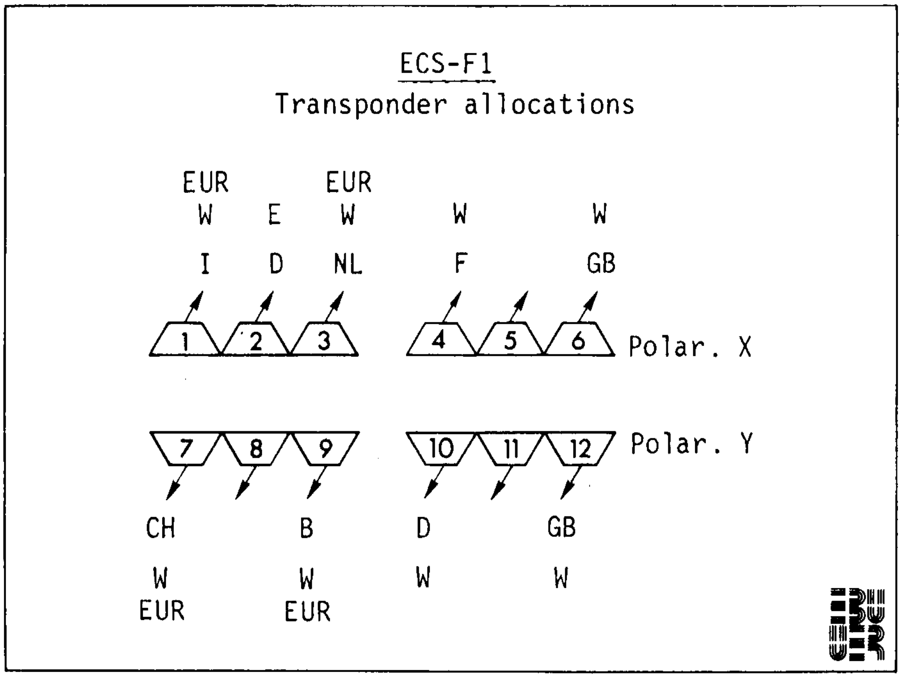
ECS-F1
Transponder allocations
EUR
W
E
EUR
W
W
W
I
D
NL
F
GB
1
2
3
4
5
6
Polar. X
7
8
9
10
11
12
Polar. Y
CH
B
D
GB
W
W
W
W
EUR
EUR

Fig. 6.

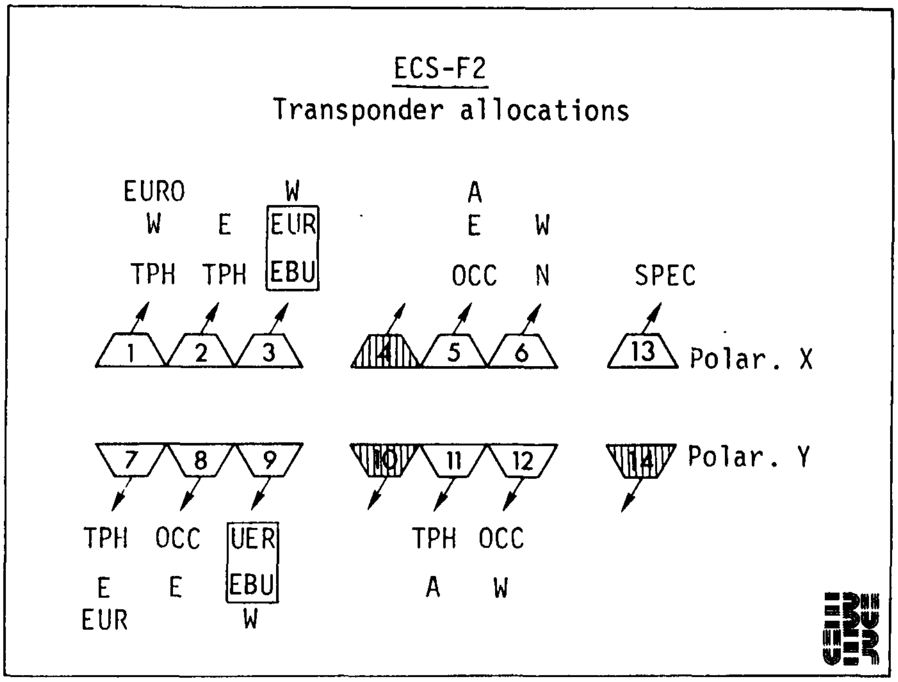

Fig. 7.

Rudolf Gressmann was born in 1920 in Hamburg, Germany, where he attended the University and received the degree of "Diplom-Physiker" in 1951. He began his professional career by joining the central technical services of the Nordwestdeutscher Rundfunk in Hamburg the following year. In 1955, he became a member of the staff of the Technical Centre of the European Broadcasting Union (EBU) in Brussels, Belgium, where he initially specialized in the preparation of international frequency-assignment plans. He was appointed Deputy Director of the EBU Technical Centre in 1972 and became its Director two years later. He is a Fellow of the Society of Motion Picture and Television Engineers (SMPTE) and a Member of the Fernseh- und Kinotechnische Gesellschaft (FKTG) and of the Nachrichtentechnische Gesellschaft (NTG). He is also a Corresponding Member of the International Broadcasting Convention (IBC) and has published numerous articles in the technical press.