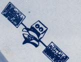
THE FIRST EDITION . . .

STTI'S International Satellite Television Reception Guidebook



By STEPHEN J. BIRKILL

World-Renowned Satellite Expert and Former Chief Engineer Of A British Broadcasting Corporation Transmitting Station

The complete guidebook to setting up a TVRO terminal almost anywhere in the world! The guide is written by probably the only man on the globe whose background and research would equip him for writing such an expansive volume — Stephen Birkill.

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STTI's International Satellite Television Reception Guidebook (1982)

by Stephen J Birkill

Warning – everything about this book is *seriously* out of date (especially the cover photo!)

I wrote STTI's International Satellite Television Reception Guidebook in 1982 – that's 39 years ago and only 20 years after the launch of the world's first active communications satellite, Telstar 1. In that first 20 years, the most significant innovation was the shift to geosynchronous satellites with steerable beams. Otherwise the technology remained much the same: the same modulation techniques and multiplexing methods, the same (more or less) frequency bands; what changed was the scale of operations. My 1982 centre-spread map documents 100 active commercial communications satellites in the geostationary ('Clarke') orbit; most of these carried 12 or more transponders, each capable of relaying one or two analogue TV services. Today the number of satellites has risen to thousands, and with shaped beams, active digital beam- and frequency- multiplexing and all-digital content, the concept of a discrete linear transponder is inadequate to define the number of simultaneous channels each 'bird' can provide.

My background was in conventional (terrestrial analogue) TV broadcasting. I'd joined the BBC in 1966, straight from university, and worked on television transmitters for 15 years, eventually becoming Transmitter Manager at the Corporation's high-power TV and FM station at Holme Moss in Yorkshire, with responsibility for the Emley Moor UHF station and numerous unattended relay stations across the north of England. Prior to that, in my teenage years I'd developed an interest in long-distance TV reception (DX-TV) from Europe, and also in amateur TV transmission (my radio and TV call-signs were G8AKQ and G6ABK/T). Then in 1975, while at the BBC, my interest in TV DX-ing was rekindled by reading about the experimental S-Band and UHF TV transmissions being made by NASA through the Applications Technology Satellite ATS-6. The satellite, originally over the USA, had been relocated to 35 degrees east as part of the SITE experiment, to demonstrate instructional TV programme distribution to remote Indian villages, and after a few calculations and rough estimates I realized it might just be possible to pick up these broadcasts at my then home in Sheffield, UK. The Indian villages were using 12-foot (3.7-metre) dishes; I had a 5-foot (1.5m) mesh dish I'd built years before for the 1296MHz amateur band (and too small to work efficiently at UHF), and I was way outside the satellite beam's target area (see image on page 63) – I knew it wouldn't be easy.

Still, I designed a feed system and 860-MHz low-noise amplifier for my 5-foot dish, and studied methods of low-threshold wideband FM demodulation. When all seemed to be working I took the dish upstairs and balanced it on a chair, looking out of the south-east-facing landing window on the appropriate bearing and elevation angle. Nothing but a screen full of noise. I persisted, and a few days later I must have hit upon the right time of day to catch the test transmissions, for emerging from the noise I could see the unmistakeable shape of 625-line sync pulse bars. This was enough to let me further optimize system sensitivity, and when a few days later I set up the dish outside in the garden I was rewarded by the sight of All-India Radio's on-screen ID.*

Encouraged by this success, I went on over the next few years to design and build experimental equipment for C-Band (4GHz) and Ku-Band (11/12GHz) satellite downlinks, and to develop further my low-threshold FM demodulators and improved antenna feed systems, the better to enable small-dish reception. In 1981 I decided to quit my (by then management-directed) career at the BBC to concentrate on satellite systems consultancy and receiver design, through my own company Real-World Technology Ltd.

Meanwhile, in the late 1970s, CATV trade publisher Robert B Cooper had brought satellite TV to homes across America, long before there were any 'direct broadcast' satellites as such. He'd learned of my 1975 work with ATS-6 and realised that it was possible for amateur electronics enthusiasts to build their own 'Television, Receive-Only' (TVRO) earth stations and effectively eavesdrop on the satellite channels used by cable TV programme providers (the likes of HBO, Showtime and WTCG/WTBS at the time) to distribute their services to cable TV head-ends across the country. All it took was a dish antenna, a low-noise amplifier (LNA) or downconverter (LNB or LNC according to whether its downconversion was in a wideband block or a single channel) and a comparatively simple receiver as indoor unit. Snag was, the low-power satellite signal demanded a dish of around 20ft (6m) aperture, though if you were content to lose the fade margin required by the Cable operators you could get by with a 12- or 16-foot dish for most channels, in most states. But then size wasn't too big an issue: the folks without CATV service generally lived outside the cities, and rural backyards could usually accommodate a big dish.

At first such things were strictly for the hobbyist: in the best traditions of popular mechanics, the enthusiast could construct a dish as large as his garden (or his neighbours) could support, and he could fit it out with a simple horn feed. It didn't need to be steerable – RCA's domestic C-Band Satcom I or II carried all the services of interest. If he (or she) was a radio amateur ('ham' in US parlance) or had some basic electronics experience he could assemble a receiver IF 'back-end' at 70MHz with an FM TV demodulator, and feed its output to the family TV. The LNA/LNB/LNC generally had to be a commercial item – its microwave techniques were quite beyond the reach of most amateurs and its semiconductors hard to obtain.

But by the end of the 1970s, thanks to Bob Cooper's publicity, the 'backyard dish' had become a desirable product, just begging to be consumerized. Bob's 'Community Antenna Television Journal' (CATJ) did much to promote this emerging (but still unofficial) direct-to-home TV market, by publicising the players and providing details of the necessary equipment – I wrote a monthly column for the journal myself, detailing some of the technologies I was using, and a number of small firms appeared with new products – dishes, mounts, feeds, receivers – aimed at the growing market.

Bob Cooper set up STTI Inc. (since defunct) and organised conventions and exhibitions in various cities across the USA, where inventors and entrepreneurs could meet with manufacturers, and dealers with the public, to license ideas and demonstrate products: an entire Las Vegas casino parking lot full of huge white dishes baking in the south-west sun was quite the sight. Bob's STTI also published a series of manuals or handbooks, each written by a pioneer in the field, to encourage private experimentation in satellite TV reception. Many enthusiasts copied the advice in the manuals, constructing their own antennas and receivers, and not a few of the ideas started to show up in commercial products displayed at the shows.

It was against this background that I was asked to create a Guidebook for the reception of international TV satellite services. I knew this would give the real enthusiasts something worth pursuing, while the home (USA) market was turning increasingly commercial. I decided to assume my reader was probably but not necessarily USA-based, and possessed a certain basic level of understanding of the technologies and terminologies of satellite TV (footprints, link budgets, polarization, FM threshold, subcarriers and the rest), so that I could concentrate on the *differences* attending 'foreign' reception and direct the reader towards trying something new and more challenging, acknowledging that most would, like myself, be constrained to using a dish very much smaller than those of the Intelsat class 'A' or 'B' terminals (typically 31m or 19m) normally employed for this kind of reception! Throughout this period I had nothing larger than my 8-foot (2.4-metre) Andrew solid dish (surplus to BBC requirements after the decommissioning of a redundant terrestrial 7GHz microwave link terminal on the old 750-foot mast at Holme Moss) and no test gear beyond my home-built spectrum analyzer, displaying sideways on a TV monitor! (The analyzer display, integrated with my narrow-band receiver – note the white rectangle ID at upper right – features in several of the screen-shots in this book.)

Satellite systems of the Soviet Union loom large here, not through any ideological preference but for the simple reason that they were at the time by far the easiest 'foreign' satellites to receive throughout the northern hemisphere. And their origin carried, especially to the US reader, a whiff of the exotic and unknown. Around this time I also collaborated with noted British space expert and Kosmos-tracker the late Geoff Perry on a series of contributions to the US Senate reports "Soviet Space Programs: 1976-80" containing my observations of the television capabilities of the various spacecraft in the Molniya and Statsionar orbits. The reports can be found in the US Library of Congress, Washington DC.

Of all the 'Coop's Manuals' this one got the luxury treatment. Printed with US 'Letter' size (11 x 8½") pages on heavyweight glossy paper and bound with staples (others had been loose-leaf) it was able to accommodate a full double-page spread for the orbital map on the centre pages (between pp.39-40), printed on one side only to facilitate pinning up as a reference poster. Yet physically it felt much like the engineering trade journals of the day, which made the $80 cover price look a little steep to this relatively impoverished Englishman! Still, Coop must have got it right – it seemed to sell well. I recall the mail-order sales returns included some very well-respected names and institutions in education, industry and government, as well as many overseas government organizations and broadcasters.

Style-wise, I found myself continuing to use the informal, attempted American-folksy tone I'd employed for my CATJ column. The language grates a little now and in places seems to me dated (datable, anyway) and unduly patronizing, but it seemed to go down well at the time and I hope you will forgive me any misjudgements and treat it as the historical document it must surely now be. Much of the content is of its moment, and many specifics became outdated in the space of a few months from printing. For this PDF release I have corrected about 20 typesetting mistakes, but apart from adding this introduction I've updated nothing. My approach was optimistic, as befits a publication for the enthusiast: the footprint maps for instance show my estimates of *typical* saturation EIRP contours rather than the worst-case, end-of-life values used by engineers for network planning. There are approximations, estimates and conjectures, but I haven't found any serious errors.

Throughout the 1980s I had advocated for Europe a regional direct-to-home system of medium power satellites of high channel-count and using conventional modulation formats, as opposed to the WARC-BS scheme of quasi-HDTV via high power satellites carrying only 5 channels per country (remember BSB?), so I particularly regret the book coming just too soon to even hint (apart from the mention of a proposed 'LuxSat' on p.75) at the analogue DTH revolution sparked by Europe's SES/Astra in 1989, the transmission parameters of which I was able to help formulate in 1988 at that historic meeting between SES (satellite), BTI (uplink), Sky (programmes), Amstrad (receiver), Concentric (dish), Marconi (LNB) and RWT (tuner). The Amstrad analogue set-top boxes, the first to be designed specifically for those parameters, employed some of the small-dish optimization techniques I touched on in this book.

As a 'Guidebook', it's spectacularly useless today, just like those receivers. But well, that's technology!

Stephen J Birkill

Vancouver, Canada, January 2021

* I later learned that this was the world's first private direct-to-home satellite TV reception, acknowledged by Bob Cooper (CSD, 1984) and Arthur C Clarke (How the World was One, 1992).

STTI's International Satellite Television Reception Guidebook

By Stephen J. Birkill

Whether your requirement is to specify or manufacture receiver hardware for the export market, to make use of overseas transmissions at home or to start a TVRO industry in your own country (on any continent), you will find in this book the information you need. EIRP levels are given throughout the book, enabling antenna size requirements to be established for all locations.

THE COVER - Stephen Birkill standing beside a satellite test antenna near his home in Grenoside, England. Stephen was born in 1946 in Barnsley, Northern England. Fascinated by radio from the age of nine, he was active as a DX-TV enthusiast and TV ham in his teens. Educated at Barnsley Holgate Grammar School and Manchester University, he joined the Transmitter Department of the British Broadcasting Corporation in 1966 as a Technical Assistant. He progressed through Transmitter Engineer and Senior Transmitter Engineer to the post of Transmitter Manager of the Holme Moss High Power TV Station by 1980.

At the present time, Steve is active in consulting work for a British company. He and his wife, Carole, have a baby son, Alexis, and live in Grenoside, a rural community on the northern fringe of Sheffield, England.

This manual has been published and is being distributed by Satellite Television Technology International, Inc., P. O. Box G, Arcadia, Oklahoma, U.S.A. 73007. The price per copy is $40. Material in this manual is believed to be current and accurate at the time of publication.

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Contacting STTI: For additional copies of this manual ($40 each) or for a complete list of other manuals offered to the TVRO enthusiast by STTI, you may contact our offices at STTI, P. O. Box G, Arcadia, OK U.S.A. 73007 (405/396-2574).

BIRKILL MANUAL

Its theme should give it a broad appeal among satellite people, but I can't help trying to imagine who you are and why you've bought (borrowed?) my book. You may be involved in the business of making or selling satellite TV terminal equipment and seeking new markets to conquer, worldwide. You may be as I was in 1975, a hobbyist in a country with no home TVRO market, hoping to find some satellite-delivered television to complement your own national TV, or just to experience the thrill of conjuring TV pictures out of space. The chances are that you will become involved in marketing, for such is the appeal of satellite TV in a new country. You may be hungry for information on the new Ku-Band satellite systems, offering the promise of high-power direct-to-home satellite TV in North America and in Europe. Or perhaps you want just to see a little foreign TV as well as the domestic product.

But first I must thank you for making the purchase. I hope you find in here the information you need, or else the inspiration and some of the know-how to set up and find it out for yourself. If the latter, you might consider sharing your findings with other readers. Most of what I've included is a direct result of my own observations and researches, moreover I believe that much of the data of an operational nature is unobtainable elsewhere, outside government sources. But I also owe thanks to a number of contacts worldwide, without whose assistance there would have been more "blind spots" in our world coverage. Inevitably some remain, and if your own observations can help illuminate (or even eliminate) them perhaps you'll spare the time to drop me a line through STTI. That way we can include the information in one of our updates to make a more complete (or correct) picture.

What this book attempts to do is simply to fill the information gap that exists between the US home terminal industry with its own 4 GHz, linear, NTSC, full-transponder chauvinism, and the rest of the world where satellite systems operate in both C-Band and Ku-Band with formats totally different to the US domsats. Worldwide, most of the information on the subject emanates from the booming US domestic satellite scene, and there is a great deal of ignorance about just what can be achieved. There have been cases of wealthy individuals from overseas visiting the US industry shows, being told the gear they see will work anywhere, lugging home a 3-meter terminal as excess baggage and then wondering why no HBO!

Over the seven years I have been involved with satellite TV, firstly as a lone enthusiast with a career in broadcast engineering, latterly as a full-time TVRO consultant, the question I have most often been asked takes the form "What will I be able to pick up in Barcelona?" (or Boston, Bombay, Brisbane, Baghdad, Bogota, Botswana, Borneo or Barnsley) and then the inextricably related "How big a dish do I need?". A study of the following pages should enable you to answer both questions, whatever your location. There is no simple answer, despite the stories the equipment salesmen may give you. The global picture is complex as you will see, though not unfathomable. Whilst the comfortable uniformity of America's domsat paradise is about to be broken by a multiplicity of Ku-Band (12 GHz downlink) systems, outside North America diversity has always been the rule. Diversity in transponder frequencies, signal bandwidths, polarizations, EIRP levels, audio formats, color systems and line standards. I have tried to explain the significance of all those differences as they impact the TVRO installation.

Throughout the book I have assumed a basic knowledge of TVRO technology, though short of the specialist engineer level. You need to know the meaning of dB, of degrees latitude, longitude, elevation, azimuth and Kelvin. You do not need any mathematics, though simple arithmetic might be useful. I expect you to have some background in the consumer/private user/home terminal side of satellite communications and be familiar with the terminology and jargon of that industry in the USA, as encountered in publications such as "Coop's Satellite Digest". For those absolutely fresh to satellite TV I recommend reading Bob Cooper's "Home Satellite TV Handbook" published by STTI, which gives all the grounding you should need.

Most readers will be US-based or influenced, so I beg in advance the forebearance of any English purists back home who might cringe at my Americanisms, in spelling: "color" for colo**u**r, "antennas" for antenna**e**(or even aerials), "meter" for met**re** (as a measure of length), and so on. Similarly in terminology: "measure" for measurement, "horizontal scan" for line deflection, etc. Other deliberate mistakes include Ku-Band when referring to 11- and 12-GHz downlinks. These are by some definitions in X-Band, but the satellite world reserves that designation for systems in the 7/8 GHz region, naming the higher band for its uplink range. The British may now suggest I mean J-Band, but that's another argument. American English is the dominant language in satellite TV, and I have tried to be consistent in its use.

Not all of the mistakes are deliberate. In my attempts to give as complete a story as possible and in the absence of definitive factual information I may in places have drawn incorrect conclusions. Our knowledge of the Soviet satellite systems is an example. Since 1976 I have used my own observations to add to the free world's knowledge of Russian comsat operations. Most sources base their data on the descriptions filed by the Russians with the International Telecommunications Union in Geneva. But these are often the first draft of a system design, to suffer many evolutions before becoming reality. Eventually up-to-date details emerge, but in the meantime (typically five years) observation is our only access to the truth. Of course official observation of the USSR's transmissions does take place, but by military and intelligence organizations which do not publish their findings. In the public domain it is civilians like ourselves who contribute to the fund of knowledge. In early articles on the subject I have given incorrect frequencies and beam patterns. For MOLNIYA, I assumed an incorrect value for argument of perigee, distorting the shape of the ground track. The error was corrected in the light of later observations, but there may be other areas described here where early observational data is presented, whose accuracy is suspect. To the best of my knowledge the contents of this book are accurate - I have tried to make it clear where there is any doubt.

The other source of error is time. The satellite TV world is dynamic, in a continuous state of flux. This applies especially to INTELSAT. In describing international telecommunications operations I do so as an outsider. Even within the organization the details are made known only to those needing to use them, minute by minute. Operational changes are communicated to interested members but they are inclined to take us by surprise. I might list toay four domestic TV leases on the 21.5°W bird, only to find tomorrow that two of them have moved to 1°W. Please bear in mind when reading this that it describes the situation at late summer 1982, plus such planned changes as had been announced up to that time. Our updates wil keep you abreast of changes subsequent to the press date.

On the domestic front I have taken the opportunity to present information on the currently-breaking wave of Ku-Band satellites turning on over North America. This is ground still new to the home industry, and is its fastest-growing segment. Transponder allocations will inevitably be developing for some time yet, as these are still early days. Hence the lack of a detailed listing. For 4 GHz US transponder occupancies, refer to SatGuide, Westsat or Satellite TV Week.

Apart from the 12 GHz systems I have not attempted to discuss reception of the North American domestic satellites within North America. If there is an intentional gap in my coverage outside that region, it is in the penetration of US domsat signals down into Central and South America, and the Caribbean. I have never gone exploring there, but Bob Cooper, Bob Behar and others are continually gathering data which advances this southern frontier. Any report here would necessarily be second-hand. Latest observations, bird by bird and transponder by transponder, can be found monthly in Coop's Satellite Digest.

In preparing this material, I have addressed the technical problems rather than the political or moral implications of installing or operating a TVRO in any given country - governments vary widely in what they allow one to receive and whether permission is required - both from country to country and from day to day. Briefly, it is wise to be aware of the licensing position in the country concerned. Some have a virtual "open skies" policy - the signals that fall on your head are yours to use as you wish unless the originator prevents you, for instance by scrambling. Others stick to the line that reception of private communications without permission is illegal, though broadcast transmissions are available to all. Special permissions may be granted for experimental, development, demonstration or export work. Certain regimes are attempting to make illegal any reception of foreign transmissions, whether broadcast or not, amounting to total censorship. Their foundations are shaky, but they could make life very unpleasant for the "offender". A few discreet enquiries might help you avoid a problem.

I hope this book can help bring satellite television to places where reception was thought impossible, to people who thought it was years away, so they can experience the thrill familiar to so many of us in this still-young industry: of pointing an antenna at what looks like empty sky and pulling in television entertainment from 22,300 miles out in space. That was the dream of English visionary Arthur C. Clarke when he proposed the geostationary satellite in 1945; it was my own ambition when I first looked for Indian Television from ATS-6 in 1975; it is fulfilled for thousands of Americans in their own homes right now. Perhaps it will be commonplace by the end of the decade, with millions tuned in to direct broadcast television from space. We don't have to wait until then!

FIRST CHOOSE YOUR SATELLITE

The chart on the center spread shows all the geostationary satellites of interest. A great many of these are some kind of telecommunications relay station, though I have also included earth observation and experimental payloads which share the 24-hour geosynchronous equatorial (Clarke) orbit.

The view is what you would see from high above the north pole, looking down on the equatorial plane. So the earth's northern hemisphere is visible at center, though not to scale. Unlike most charts of this type which have been published, this one aims to represent the **actual** state of the orbit at epoch summer 1982 (approximately), rather than an **idealized** version with everyone in his place. So for instance I have not included Intelsats in transit, nor the Soviet "Statsionar" designations which may or may not be occupied at this time. It is not relevant here to show vacant Intelsat slots (29.5°W, 66°E) or Statsionar slots (45°E, 140°E) for example. Likewise projected service dates shown for future spacecraft are **realistic** estimates, where **optimistic** ones have been encountered. For the same reason I have not cluttered the chart with projections which have not yet been allocated orbital slots, though they may be claiming them (e.g. the US DBS).

Obsolete satellites are now, where possible, "kicked" out of geosynchronous orbit before the last of their station-keeping fuel is exhausted, to save them drifting uncontrolled through the orbital belt as a collision hazard, before eventually settling into one of the two gravitational wells near 75°E and 105°W. At geosynchronous altitude a spacecraft is well above atmospheric drag, and orbital lifetimes are measured in millions of years. Operational lifetimes aren't quite so long, working out around 2 to 5 years for Soviet comsats, 5, 7, 10 years or longer for American and European birds. End of life may be precipitated by equipment failure but more usually it is determined by fuel capacity (versus stationkeeping regime) or operational obsolescence. Obsolete satellites still on station and theoretically available for use (certain INTELSAT III birds for instance) are not shown. ANIK A-1 will be deleted from the next edition. More recent birds, raised or lowered in orbit at the end of their lives, have a daily drift rate of several degrees and so cannot be shown. They are of no further use or interest (e.g. CTS, ATS-6, WESTAR-2, METEOSAT-1).

To use this book, your first action is to determine just which satellites are in view from your (or your client's) location. The look angle equations are well known and I shall not repeat them here. They are most convenient in microcomputer program form, though custom printouts are available. Fig. 2 shows them plotted in graphic form.

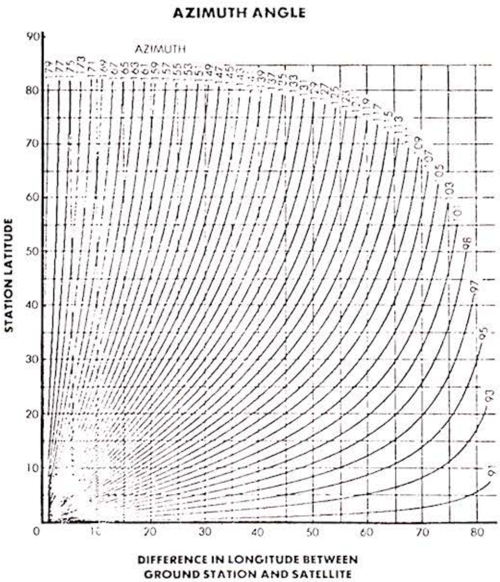


FIGURE 2a.

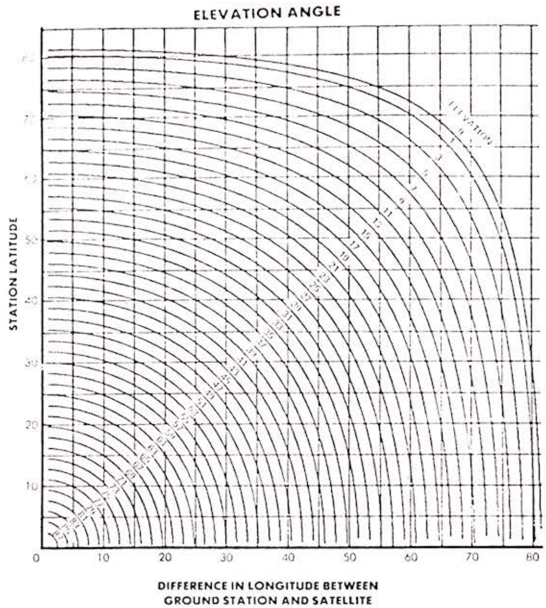


FIGURE 2b.

Zero elevation defines the satellite's horizon (global beam-edge) but is of academic interest - an elevation angle of at least some two degrees is required in practice to separate the satellite signals from terrestrial thermal noise. Receiving antenna noise temperature degrades very rapidly down towards the horizon, and commercial installations usually demand elevation angles of at least five degrees, being happier with ten. Here we shall encourage you to attempt reception down to the two degree figure, if your horizon is clear so far down on the required bearing (azimuth). From Fig. 2a you will see the arc of sky included above two degrees depends on your latitude. At latitude 40° you'll see satellites displaced 76° in longitude east and west of you, a total arc of 152°. At latitude 50° this becomes ± 73° and at latitude 60° your arc is ± 68°. Above latitude 79° you lose two degree sight of all geostationary birds, even one right on your own meridian. In northern latitudes you'll then be limited to MOLNIYA, but within 750 miles of the South Pole you'd better take tapes.

These arcs assume a true geostationary bird, in a perfectly circular equatorial (zero inclination) orbit. Elliptical or inclined orbit geosynchronous satellites have greater visibility for twelve hours, then lesser visibility for twelve hours, in each 24-hour period. For continuous service you'll need to see the mean geostationary point at a higher elevation, by approximately the value of the inclination angle (see SYMPHONIE).

Having worked out your visibility limits you can draw them in on the chart, as two radial lines starting at the center ("N" on the globe), intersecting the longitude scale at the two points corresponding to your "2-degree horizon" and extending outwards through the satellite names and symbols.

Between these two lines you should now have a bunch of satellites to consider. Look at those in the central region first, as they will undoubtedly be easiest to receive - as well as their higher look angles they are more likely to be boresighted in your general direction. Remember there are special problems inherent in elevation angles below ten degrees, and you may well find the site is obstructed at low look angles, by trees, buildings or hills.

Next consider the downlink frequency band. Most of the triangular symbols are of no interest, representing non-TV downlinks in VHF, UHF, L-Band, S-Band, X-Band or experimental higher frequencies. The exceptions are INSAT, ARABSAT and EKRAN, with S-Band or UHF direct broadcast TV downlinks.

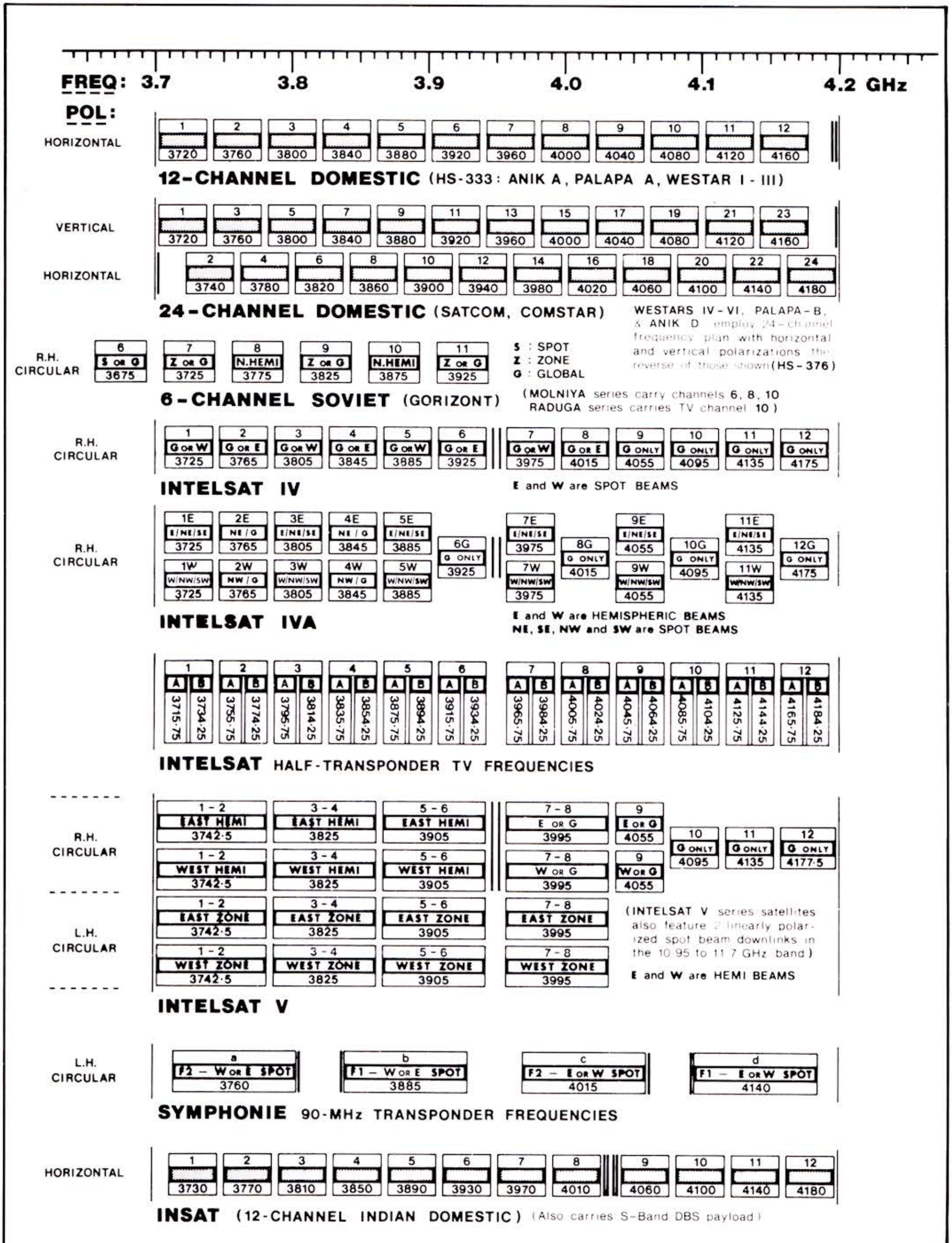


FIGURE 3. TRANSPONDER FREQUENCIES, C-BAND SYSTEMS

The remainder will be classified as C-Band or Ku-Band, and may or may not carry TV. In general C-Band downlinks are in the familiar frequency range 3.7 to 4.2 GHz, though the Russians use frequencies right down to 3.4 GHz. (See Transponder Frequencies). Ku-Band here refers to downlinks between 10.95 and 12.75 GHz, encompassing the 11 GHz fixed-satellite service band and the 12 GHz direct-broadcast band, as well as the 12.5 GHz European business communications allocation. (Precise limits vary between ITU regions 1, 2 and 3).

The MARISAT and MARECS satellites have narrowband 4 GHz downlinks without television capability though they do appear on the chart. Later INTELSAT V birds carry a similar maritime MCS package. Surviving ATS satellites operate only on VHF though they do possess C-Band capacity. This is not shown on the chart.

If the satellite carries regular or even occasional TV transmissions it will be mentioned in the appropriate section of the book, with footprint data where available.

TRANSPONDER FREQUENCIES

C-Band (Fig. 3)

INTELSAT IV was the first satellite series to channelize extensively. 36 MHz had been selected as the most versatile RF channel width, and twelve channels, with guard bands, could be accommodated in the 3.7 - 4.2 GHz downlink band (uplinks in the region of 6 GHz, 2225 MHz higher than the downlink frequency).

The twelve were disposed symmetrically about the two existing telemetry frequencies (3947.5 and 3952.5 MHz) adopted for previous generations of INTELSAT, forming two groups of six on 40 MHz centers. While sharing the redundant on-board receiver and downconverter, each channel on the satellite had its own transmit chain and traveling-wave tube amplifier (TWTA) and became known as a **transponder**. Multiplexing and demultiplexing filters prevented interaction between transponders. Each could handle single or multiple-access communications within its own slice of spectrum.

Shortly afterwards the first North American domestic communications satellites appeared (ANIK, WESTAR), also with twelve channels but in a different pattern, asymmetrically placed within the band to allow half-channel offset spectrum re-use to be applied in later systems (SATCOM, COMSTAR). This re-use option results in a total of 24 transponders and gives rise to the 1 - 24 channelization encountered in U.S. receivers.

In addition to the half-channel offset, isolation between odd- and even-numbered channels is achieved by **cross-polarizing** the two sets. The two orthogonal linear polarizations are termed vertical and horizontal, this referring to the direction of the radiated electric field vector in the meridian plane of the satellite - **they do not generally correspond to local vertical and horizontal at the receive terminal**. Correct polarization angle is best set by rotating the antenna feed system to a sharp **null** on one set, then rotating again through 90 degrees.

The domestic 12- and 24-channel patterns appear at the top of Fig. 3 with their channel center frequencies in Megahertz. The telemetry beacons are represented by the short vertical lines just inside the band edges. The 12-channel pattern is employed by the first generation of domsats, built around the Hughes HS-333 spacecraft bus. These include the ANIK A and PALAPA A series, and WESTARs I - III. The ANIK B and TDRS/ADVANCED WESTAR C-Band payloads also comply with this scheme. The 24-channel pattern is the most familiar to American readers, being used by SATCOM and COMSTAR satellites and, in modified form, by the new generation HS-376 birds of WESTAR IV - VI, ANIK D and PALAPA B. These use different channel numberings and reverse the vertical and horizontal assignments, compared to SATCOM and COMSTAR.

A glance at the remainder of Fig. 3 will reveal that in general transponder frequencies in the rest of the world don't match those of the American domsats. The diagram itself provides a translation, but for the benefit of those with 24-channel tunable receivers I shall indicate by the use of square brackets [ ] the **nearest equivalent SATCOM transponder number** when referring to other channelization schemes. Hence Sudan is on INTELSAT 21.5°W tpdr 7A[13] and Soviet II Programma, Dubl'-III is on GORIZONT 53°E channel 10 [9].

For a detailed discussion of transponder beam allocations and frequency re-use for these systems, see the appropriate section.

North American and Japanese Ku-Band (Fig.4)

These systems all operate within the "**12 GHz**" downlink band, 11.7 to 12.2 GHz of the American domestic fixed-satellite service, although some will be carrying pilot or interim direct (to home) television broadcasting, while Japan's BSE is primarily an experimental DBS. For details in each case see section corresponding to satellite name.

The use of this frequency band for "interim DBS" is permitted according to the **World Administrative Radio Conference** (WARC) of 1979, which made the most recent adjustments to satellite communication frequency allocations. In the American continent (ITU Region 2) before 1979, the 11.7 to 12.2 GHz downlink band was shared between the fixed and broadcasting satellite services (FSS and BSS). WARC-79 determined that, besides orbital arc segmentation between the two systems, FSS should have primary use of 11.7 to 12.1 while BSS would rule from 12.3 to 12.7 GHz. The disputed central region, 12.1 to 12.3 GHz, the two services would share on an equal basis, at least until 1983 when a Regional Administrative Radio Conference (RARC) will determine the break point (probably 12.2 GHz) and establish a detailed DBS plan for the Americas. So fixed service satellites (like ANIK C) were permitted to offer DBS subject to a maximum EIRP constraint of 53 dBW (decibels above one watt) per channel.

This all points towards America having DBS EIRP levels below those of Europe, more in line with today's microwave receiver technology, plus the possibility of DBS receivers combining the FSS and BSS bands (11.7 to 12.7 GHz) and blurring the distinction, as has already happened at 4 GHz where home terminals have turned the FSS into a virtual DBS, albeit requiring a 3-meter antenna.

European and global Ku-Band (Fig. 5)

Three distinct bands are covered here. Firstly the "11 GHz" fixed-satellite service band, actually two sub-bands,

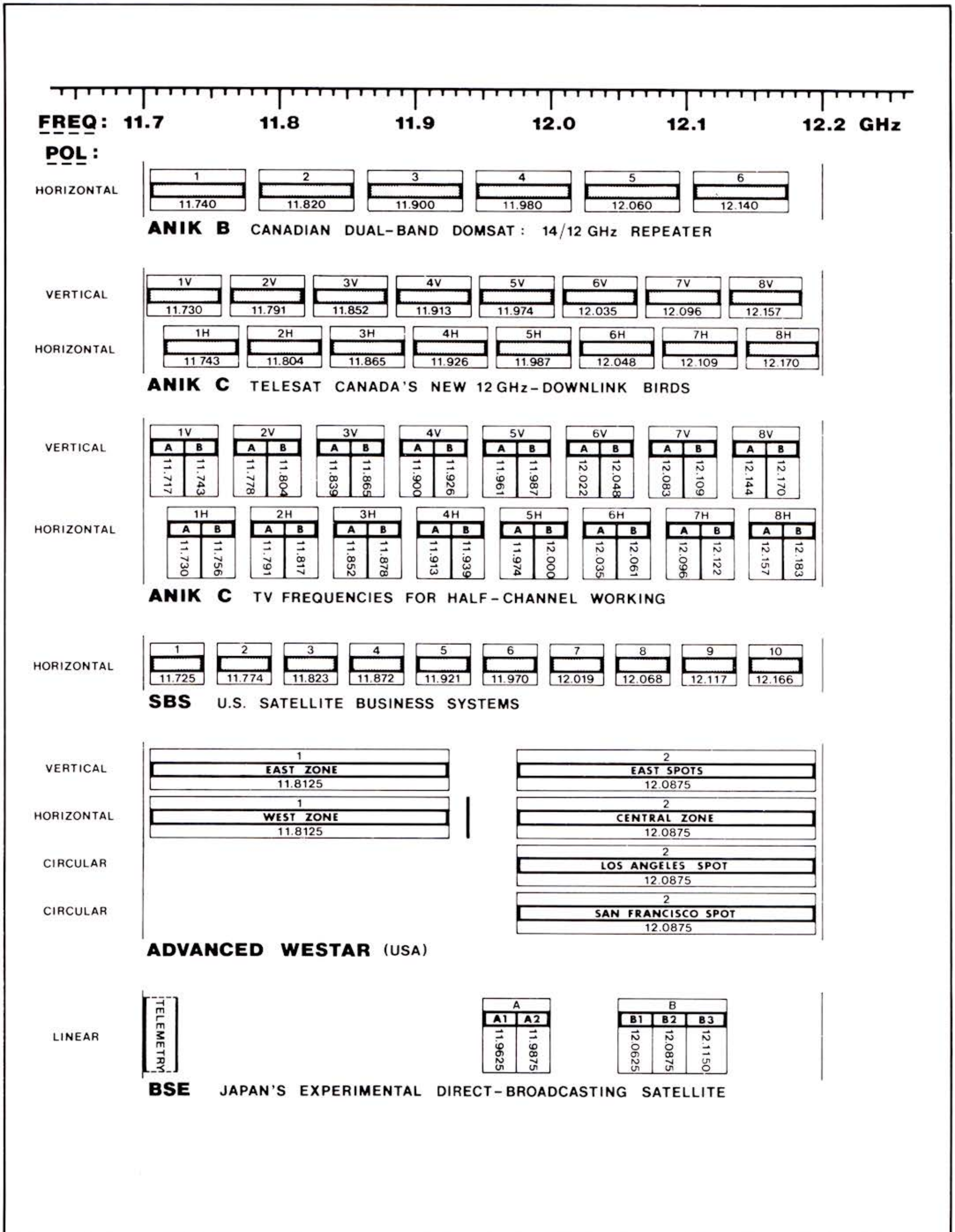


FIGURE 4. TRANSPONDER FREQUENCIES, NORTH AMERICAN AND JAPANESE Ku-BAND SYSTEMS

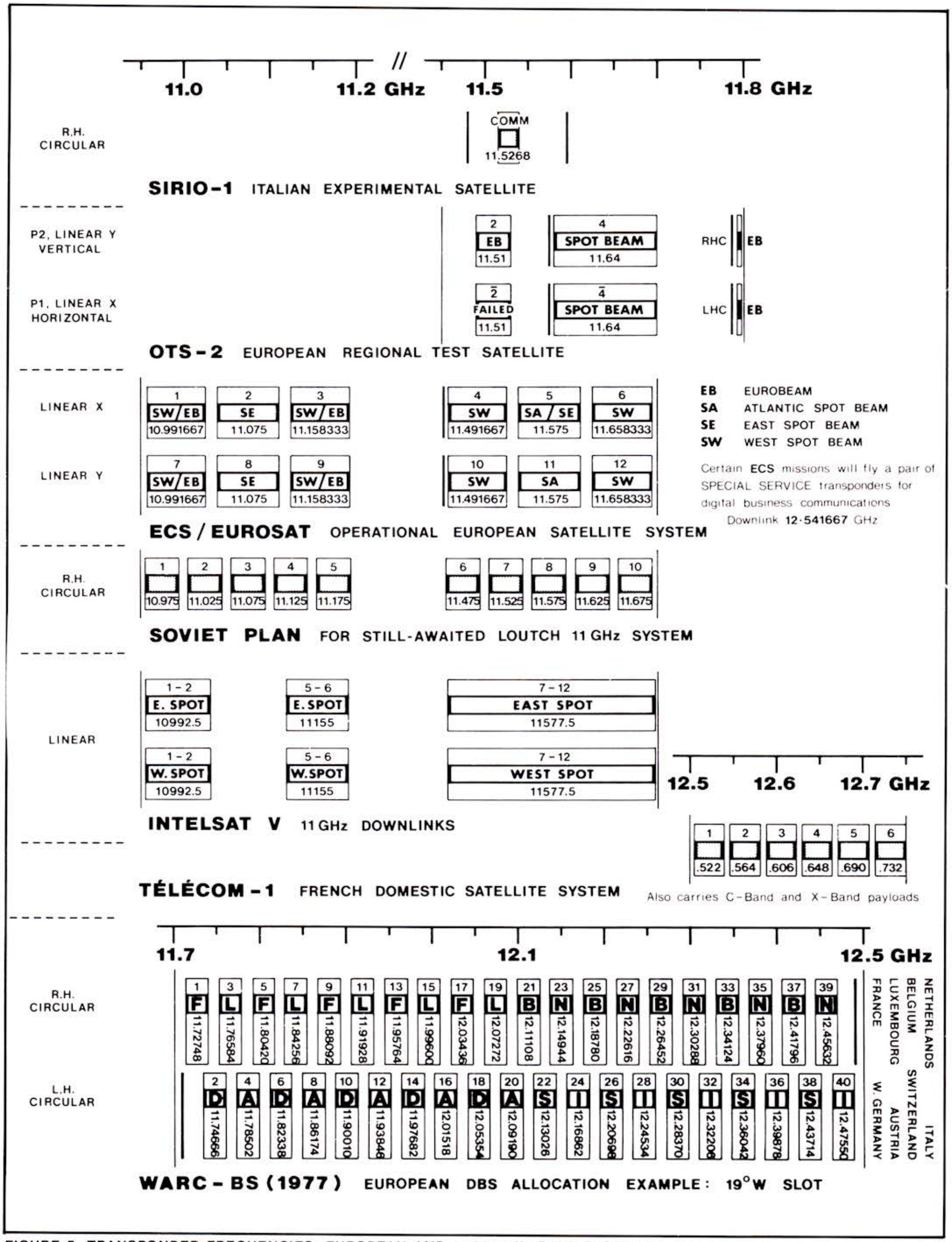


FIGURE 5. TRANSPONDER FREQUENCIES, EUROPEAN AND GLOBAL Ku-BAND SYSTEMS

10.95 to 11.20 GHz and 11.45 to 11.70 GHz. Then the "12 GHz" DBS band, an 800 MHz chunk from 11.7 to 12.5 GHz. Finally, we have the business satellite service allocation for ITU Region 1 (Europe, USSR and Africa), from 12.5 to 12.75 GHz.

The 11.7 to 12.5 GHz DBS allocations for Regions 1 and 3 (Fig.6) were determined at **WARC-BS** in 1977, when transmission parameters, orbital locations, footprint zones, channel frequencies and polarizations were allocated for all countries outside ITU Region 2.

In Region 1 the DBS parameters are based on forty 27-MHz channels, spaced 19.18 MHz with orthogonal circular polarizations between adjacent channels. EIRP assumes a receiver sensitivity of 6 dB/K (individual reception) requiring a power flux density of -103 dBW/m^2 at the edge of the service area, for 99% of the worst month. This equates to an EIRP value in the region of 62 to 68 dBW at edge of coverage zone, dependent on country. In region 3 the equivalent PFD is -111 dBW/m^2, requiring a less extravagant EIRP of 55 dBW beam-edge. Orbital slots are spaced 6 degrees in longitude.

Fig. 5 includes a typical European DBS allocation, that for the orbital slot of 19°W - probably the first to be activated according to the Geneva plan.

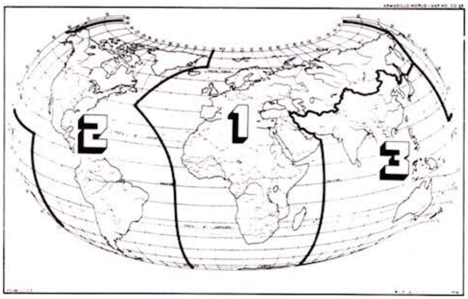


FIGURE 6. ITU TELECOMMUNICATIONS REGIONS 1, 2 and 3

NORTH AMERICAN Ku-BAND SYSTEMS

ANIK B

This "stop-gap" hybrid (dual-band) bird from RCA gave North America its first operational (as opposed to experimental) Ku-Band service, beginning in early 1979. Six channels, each of 72 MHz usable bandwidth, serve Canada via four "quarter-Canada" spot beams. Beam edge EIRP is 47 dBW nominal in a single spot beam, 44 dBW for combined (east or west) pairs of spot beams. Four 20W TWTAs are provided, permitting only four channels to operate simultaneously, at saturated power levels. Footprint patterns are similar to those for ANIK C-3 (Fig. 7) but perhaps 2 dB lower in level. Little data have emerged on ANIK B's southward coverage at Ku-Band, though its C-Band transponders, 2 dB more powerful than those on the ANIK A series, have produced some pleasant surprises in the southern states and the Caribbean.

ANIK C

Telesat Canada's second-generation Ku-Band satellites are built around the Hughes Aircraft HS-376 spin-stabilized platform. Twenty 15-watt TWTAs are carried, 16 of these serving 8 channels on each polarization of a frequency re-use plan. Two pairs of spot beams, each of 1° x 2° beamwidth, are generated by a cluster of horns feeding the same offset paraboloid reflector. The output of each TWTA may be selected to either of the two (quarter-Canada) spot beams serving its own polarization (vertical west, horizontal east) or may be divided equally between them, giving a weaker "half-Canada" (1° by 4° approx) beam.

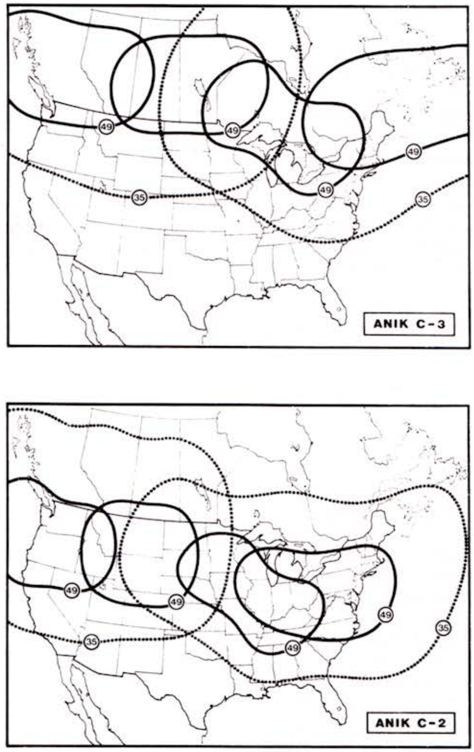


FIGURE 7. PROBABLE REAL-WORLD EIRP CONTOURS FOR CANADIAN Ku-BAND SATELLITES

A channel width of 54 MHz was chosen, sufficient to carry the 91 Mb/s bitstream resulting from the combination of two 45 Mb/s digital telephony streams, a total of 1344 voice channels per transponder. 54 MHz transponder bandwidth is also ideally suited for transmission of two half-channel television carriers, each of standard FM format. This is achieved by **offsetting** the TV carriers by plus and minus 13 MHz from channel center frequency. Since the frequency re-use mode offsets vertical and horizontal channels by the same 13 MHz, it has the happy result of interleaving the cross-polarized TV signals in such a way that carrier frequency on one polarization falls in a gap in the frequency spectrum of the opposite polarization, so providing an extra measure of protection against interference. Fig. 4 lists the resulting **half-transponder** TV frequencies.

The disadvantage of half-channel working is the **power sharing** involved. The traveling-wave tube (TWT) amplifier's 15-watt output has to be split between carriers (3 dB) and also **backed off** from saturation by a further 3 to 4 dB to control the degree of intermodulation between the two carriers. This in addition to the 3 dB EIRP reduction involved in serving two spot beams to give half-Canada coverage. So what for full-channel TV in one spot beam would be 49 dBW EIRP, becomes in practice 39 dBW. Good for the large Telesat terminals of 26.5 dB/K, but hardly DBS.

One feature of 12 GHz systems that works in favor of the small terminal is the need to build in large system margins to cope with unpredictable atmospheric factors. Whereas the system may be designed for 0.1% of the time to be lost to rain outage without the use of spatial diversity, for home reception a very much greater outage could be tolerated, say 1% or even 5% of the time. So immediately the private user can discard the fade margin (up to 10 dB) demanded within the service. The dBs so won can be put back elsewhere. Inside the 49 dBW contour (nominal beam-edge minimum 47 dBW, but predicted to be exceeded by up to 2 dB), for full transponder TV (i.e. transponder saturation), clear weather power flux density on the ground is some -114 dBW/m^2. Our "marginal system" could compromise a 70 cm dish with a 3 dB LNC noise figure and threshold-extension demodulator. Now that is DBS! More realistically, for 13 dB carrier to noise ratio (C/N or CNR) in a 25 MHz IF bandwidth with a 3.8 dB LNC, an antenna size of 1.4 meters would be required.

With these kinds of figures in mind, American DBS is on its way even before RARC-83 has sat down. It now appears that ANIK C-2, the second to fly (April 1983) will have its antenna boresight adjusted southwestwards by a little over half a degree, so illuminating primarily the northern United States, from Washington state to New England and extending southwards as far as northern California, Colorado, Tennessee and North Carolina. Almost the entire northern half of the United States is due to receive a minimum of 47 dBW from the four primary spot beams, while the secondary service area resulting from the combination of the eastern and western pairs of beams is now defined out to the 31 dBW (min) contour, and takes in the remainder of the contiguous US with the exception of Texas, Florida and the extreme southerly regions of California, Arizona, New Mexico and Louisiana. Also in this portion of the footprint are those parts of Canada originally planned for 47 dBW service.

US and Canadian telecommunications policies have traditionally been very different, Canada favoring tighter regulation and fearing cultural domination. Letters of Agreement were exchanged in 1972 between the two governments, permitting the sharing of transponder capacity in both directions in the event of one country's shortage coinciding with the other's spare capacity. A condition of the agreement was that any satellite signal be used only in its country of origin, and that each case be approved by both countries' regulator bodies (the FCC and the CRTC).

Interest in "interim DBS" was high. GSat (GTE Satellite Corporation) will fly its own Ku-Band satellites beginning in 1984, but requires immediate capacity to deliver a selection of broadcast, Pay-TV and cable services to American users including SMATV systems. Oak Satellite Corporation, a subsidiary of encryption system manufacturers Oak Industries, is entering the DBS race with its own 12 GHz bird tentatively planned for 1986, but wants to expand its existing terrestrial STV service by adding satellite delivery in 1983. Both would employ scrambling.

The initial proposal, regulatory approval forthcoming, was for the first ANIK C (C-3, due for Shuttle launch November 1982) to carry 10 transponders of GSat service, and for Oak's four channels to fly on C-2 in April 1983. This would have meant applying the southwesterly antenna tilt to both birds, placing Canadian users at a disadvantage. In particular, Canadian cable and DBS operators opposed the plan, and Telesat had to consider moving the GSat service to the C-2 bird or losing approval. As it happened, GSat themselves chose to delay the start of their service to June 1983, which meant that the transfer to C-2 was agreeable to all concerned. So it appears that C-3 will retain the original Canadian boresight (Fig. 7) and C-2 will take to the sky in April 1983 (service by mid-June), providing the US services with the footprints of Fig. 8. The third ANIK, C-1, is due for launch in April 1984. By that time several new US domsats will be entering service and C-1 is expected to be aimed towards Canada.

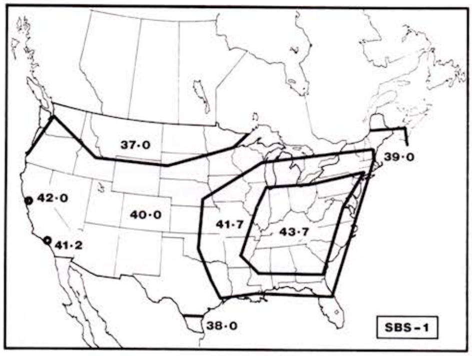


FIGURE 9. SBS EIRP MASK. THIS IS THE MORE OPTIMISTIC OF TWO PUBLISHED VERSIONS.

SBS

Satellite Business Systems operates two HS-376 class satellites, with a third launching November 1982. Ten transponders of 43 MHz each are accommodated with single linear polarization in the band 11.7 to 12.2 GHz (Fig. 4). Actual footprint data is not available, but the specification mask is shown in Fig.9. The system is designed for all types of commercial message and data communication, using the digital **TDMA** system (Time Division Multiple-Access), offering data rates up to 1.5 Mb/s, with 6.3 Mb/s available if the demand arises. The Ku-Band allocation permits siting of terminals on down-town premises without terrestrial interference constraints. Standard SBS user's terminal is 5 or 5.5 meters for rooftop mounting, with a maximum of 7.7 meters being required in the extreme northern or southern regions of the continental US, where EIRP falls below 40 dBW.

SBS could in principle be used to provide a limited pre-operational DBS capability, though EIRP is less attractive than ANIK C. Two SBS-2 transponders were leased for TV relay in August 1980, but interest seems to have been low. None of my US correspondents seem to be equipped for 12 GHz reception, so the present TV transponder usage is not known.

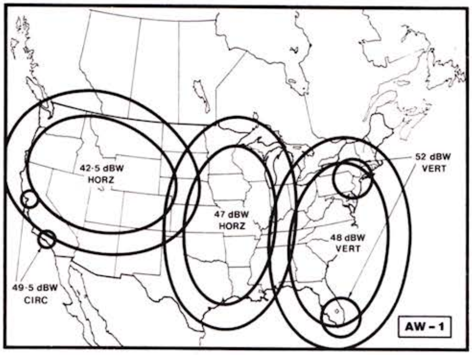


FIGURE 10. SPECIFICATION CONUS EIRP FOR ADVANCED WESTAR.

ADVANCED WESTAR

This is the commercial version of the TDRS (Tracking and Data Relay Satellite) System of NASA. The Ku-Band communications package is designed for **SS-TDMA** (Satellite Switched Time Division Multiple Access) traffic, downlinking in multiple beams (Fig. 10), beam assignment being controlled by the on-board 4 x 4 way TDMA switch. This can route data bursts between any pair of uplink and downlink beams within a frame period of 750 microseconds. QPSK data rate is 250 Mb/s (megabits per second) per transponder, 1000 Mb/s in all. The four main switch outputs (east, west and central zones, and east spots) drive four 30W TWT amplifiers, with two spares available. The west coast spot beams are fed from two 1.5 W TWTAs, multiplexed at IF with the western zone output. Again two spares are provided. Fig. 4 shows transponder/beam assignments and polarizations.

Hard limiting is employed at intermediate frequency in each Ku-Band transmission channel, making the 225 MHz bandwidth unsuitable for FDMA operation. Though designed to operate with the all-digital AW SS-TDMA network, and of course capable of carrying digital video signals, there seems to be no reason why the full power of a 225 MHz transponder could not be made available to a 36 MHz or 25 MHz FM TV signal within that bandwidth. The TDRS/AW "spare" bird at 79°W will be essentially uncommitted, apart from occasional contingency use by NASA, and represents a valuable resource. Western Union feels that industry will be slow to take up the high-speed data capabilities of the AW network, and that the "spare" satellite will provide the ideal vehicle for an interim DBS-type service, with EIRPs high enough to serve TVRO antennas in the 1 to 1.5 meter range, for 60% of American homes. Additionally, the bandwidth is available to accommodate experimental transmission of the proposed high-definition and wide-screen TV standards which may one day allow the home TV screen to do full justice to the 70 mm movie-maker's product.

DBS IN JAPAN

The world's second high power Ku-Band experimental direct-broadcast TV satellite was Japanese. After CTS (Hermes), a joint venture between the USA and Canada, Japan acquired BSE-1, the "Medium Scale Broadcasting Satellite for Experimental Purpose". The General Electric Company of USA worked with Japan's Toshiba to produce the first flight model, which was launched by Delta rocket from KSC in 1978.

Two wide-band transponders of 100-watt saturated output made up the communications payload, downlinking in the 12 GHz band. The transponders were channelized into four slots of 25 MHz and one of 30 MHz (Fig. 4), though each would be used to carry only one TV channel at a time.

From its orbital location over 110°E, BSE-1 illuminated a shaped beam (Fig.11), placing a minimum of 55 dBW EIRP per channel over the Japanese "mainland" islands, and 46 dBW to the remote islands. The 38 dBW contour shown here is an estimate of EIRP further out from boresight. Hong Kong and the Philippines are beyond this line, suggesting an antenna requirement of 3 to 6 meters for marginal reception. Field tests will be necessary.

BSE-1 broadcast the experimental TV transmissions for only 2 years of its 3-year design life, owing to premature failure of the high power traveling-wave tubes on board. Nevertheless it enabled the Japanese to prove their DBS receiver technology and gain operational familiarity with 12 GHz receiving hardware. Standard format was 525 lines NTSC with 4.5 MHz and 5.05 MHz audio subcarriers, in a 25 MHz channel width. Experimental receivers used the Konishi mixer, 3.8 dB typical noise figure, with 1.6 meter and smaller antennas on the mainland, up to 4.5 meters on the outlying islands, including allowance for rain margin.

BSE-2 is expected to be launched in September 1982 from Japan's Tanegashima Space Center, and will provide further pre-operational service until the Japanese launch their BS-2 series, in 1984 and 1985. This pair of DBS birds will provide primary and spare capacity for operational 2-channel NHK broadcast service, until BS-3 and -4 are available for 8-channel coverage, including a subscription channel, towards the end of the decade. Footprint patterns are expected to be similar to those of BSE, or a few dB "hotter"

11/12 GHz RECEIVER SYSTEMS

It is not the aim of this book to go into technical or design details of receivers. I do not see a significant amount of "home brewing" taking place at these more difficult higher frequencies. My own development receiver from 1978 is shown in block schematic form in Fig. 12, together with the type of architecture being con-

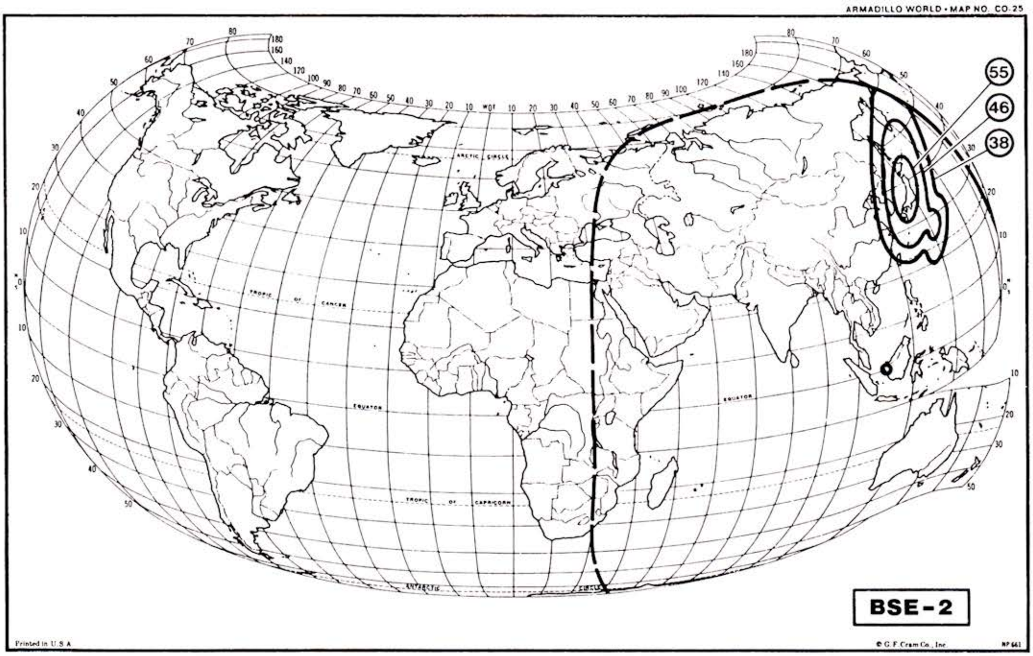


FIGURE 11. FOOTPRINT OF JAPAN'S BSE. BROKEN LINE IS SATELLITE'S VISIBILITY LIMIT AND SHOULD NOT BE TAKEN TO IMPLY ANY USABLE SIGNAL LEVEL.

sidered by today's designers. Most of the first generation 12 GHz receivers seem to use the fin-line (planar circuit in waveguide) approach pioneered by Dr Y Konishi of NHK Labs. This image-recovery (not image-rejection) mixer will yield an overall receiver noise figure of typically 3.8 dB (405°K). It is combined with an extremely stable dielectric-resonator stabilized FET oscillator in a unit by DX Antenna Company of Japan, and marketed under several different names in the USA.

It must not be overlooked that a 12 GHz antenna requires a surface tolerance, pointing accuracy and stability 3 times as good as a 4 GHz antenna of the same aperture.

INTELSAT

The 107-nation **International Telecommunications Satellite Organization** operates our primary global communications network with some 17 spacecraft of three types, distributed over the three major ocean regions, Atlantic, Pacific and Indian.

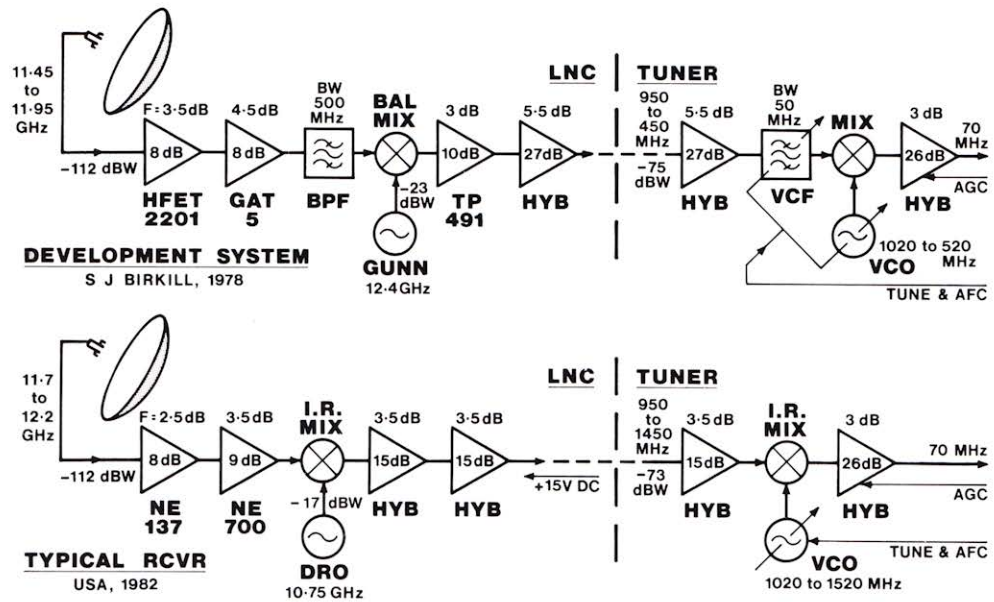
The great majority of international television, telephone, telex and data communications go via the INTELSAT system. INTELSAT has many classes of service to suit the requirements of its members, but in general all access to the global system must be made through the international "gateway" centers operated by the telecommunications authorities (PTTs) of the member nations.

INTELSAT demands very high standards of its members, in the matter of earth station performance. A C-Band standard "A" station must have a minimum G/T figure of merit of 40.7 dB/K, requiring an antenna in the 26 to 30-meter range with a cooled parametric LNA. The equivalent figure for standard "B" is 31.7 dB/K, from an antenna in the 9- to 11-meter class. At 11.2 GHz the standard "C" terminal needs to meet or exceed 39 dB/K, requiring a 19 or 20-meter antenna.

This all makes INTELSAT TV reception sound very expensive. Even a receive-only terminal meeting these specifications could cost hundreds of thousands of dollars from the suppliers of Intelsat ground segment hardware.

Yet, there are increasing numbers of small (6 meters or less) terminals now receiving adequate quality TV from certain INTELSAT downlinks in all parts of the world, as I shall explain.

First we need to examine the classes of INTELSAT birds and their beam patterns. The fundamental coverage pattern is known as a **Global Beam**. That isn't meant to imply that it covers the entire Earth's surface, merely the 40% or so which is visible from any one geostationary location. Traditionally the edge of a beam is defined by its half-power contour, 3 dB below the beam center (boresight) level. Take Fig. 13 as an example. This shows an INTELSAT IV global beam. The 22 dBW beam-edge contour corresponds effectively to the visibility limit of the satellite, the **horizon** where a ray from the satellite is **tangential** to the Earth's surface. At any point on this line of contact, the satellite is also on the terrestrial horizon, **and its elevation is 0°**. For some purposes, global beam-edge is defined by a ten-degree look angle from the



11/12 GHz RF/IF SCHEMATICS

FIGURE 12.

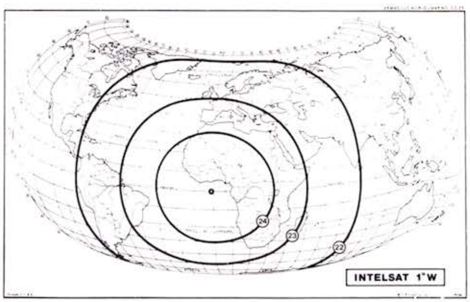


FIGURE 13. TYPICAL INTELSAT 'GLOBAL' BEAM

earth station, or an 8.6 degree radial offset from the subsatellite point, but the difference is a small part of a dB.

The center of the global beam is (at least) 3 dB higher in radiated power, here some 25 dBW, and coincides with the subsatellite point, on the equator 1° west of Greenwich. This idealized footprint shows the approximate EIRP contours as they intersect the Earth's surface. **As with most of the footprints presented in this book the EIRP values are those corresponding to single carrier saturation of the transponder**, and are **not** necessarily realized operationally. I shall make clear what is to be expected in each case.

Beam edge doesn't **have** to be 3 dB below maximum. An ideal Earth illumination pattern would deliver an edge-of-earth EIRP 1.7 dB **higher** than the subsatellite point EIRP, to compensate for increased spreading on the longer path. The result would be essentially **even illumination** (in power flux density terms) of all points within the visibility limit. Near-ideal antennas are being developed for future global beam services. The 3 dB-down beam edge normally encountered is a function of the simple conical earth-coverage horns on existing satellites. Moreover, the beam center (boresight) gain or EIRP is the only fundamental value, and the relative level of "beam edge" can be quite arbitrary. Europe's 11 GHz OTS defined beam edge as 6.5 dB below boresight level, accepting this EIRP (and hence PFD) variation over the defined coverage zone in exchange for a high value in the center. INTELSAT's concern is to provide a certain minimum value of spacecraft G/T and EIRP at the edge of previously defined coverage areas, so in their case beam edge is all important. Maximum EIRP values in hemispheric beams can be as much as 4.5 dB above beam-edge level, which itself may be 1 to 2 dB higher than the minimum specification at beginning of life. As the transponder TWTs age, so their powers decline. Many of the INTELSAT IV birds are well past retirement age, having survived ten or eleven years of a seven-year design life. Not surprisingly certain transponders on these old birds are looking a little sick and may be saturating early, or requiring excessive output backoff to meet intermod specs.

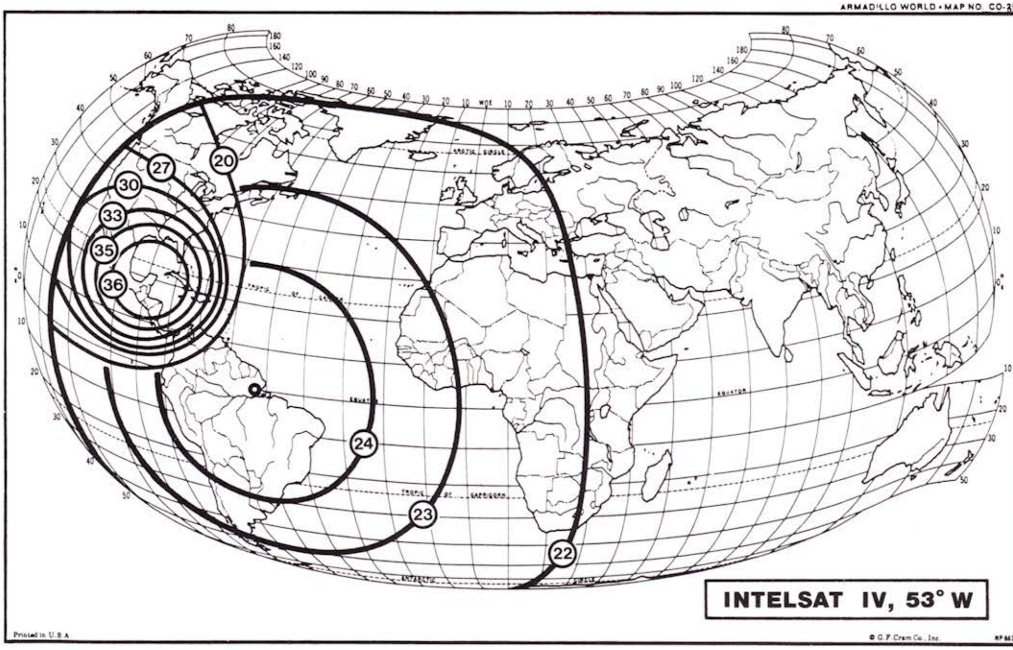


FIGURE14. INTELSAT IV GLOBAL AND SPOT BEAMS (SATURATED EIRP)

INTELSAT IV

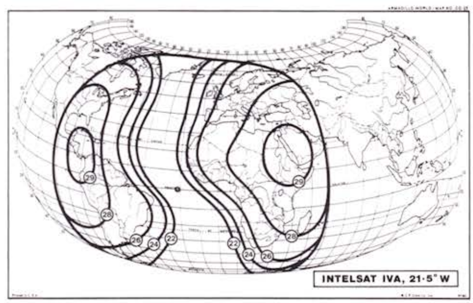
The INTELSAT IV series, 7 satellites in orbit (service or spare) were launched between 1971 and 1975. Hughes Aircraft Company was the main contractor. The dual spin-stabilized spacecraft were doubly innovative: not only multiple transponders (INTELSAT III carried two FDMA repeaters) but also steerable spot beams. The despun antenna assembly includes two independently-steered paraboloids generating **4.5-degree pencil beams**. The gain of these antennas enables the standard 6-watt TWTAs to yield an EIRP in the region of 33.7 to 34.5 dBW beam-edge at saturation - around 37 dBW maximum EIRP.

Fig. 14 shows such an INTELSAT IV spot beam, **saturated** EIRP contours from a satellite over 53°W centering its beam on the Yucatan peninsula. The global beam footprint is included for comparison.

Referring back to the transponder frequencies chart, Fig. 3, it can be seen that only transponders 1 to 8 inclusive have access to the spot beams, odd numbers to the western and even numbers to the eastern spot, with optional switching to global pattern horn. Transponders 9-12 are permanently global.

INTELSAT IVA

With the ever-increasing world demand for international telecommunications, INTELSAT found it necessary to increase the capacity of the global system before its new generation of satellites (INTELSAT V) were due to fly. The solution adopted was a modified INTELSAT IV



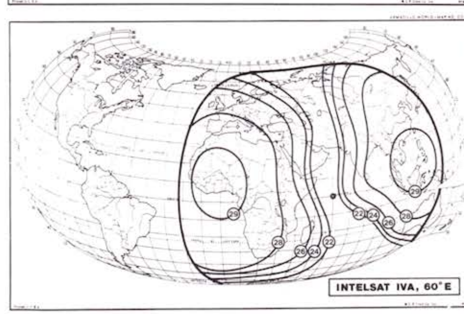


FIGURE 15 & 16. INTELSAT IVA: SIMPLIFIED HEMISHPERIC BEAM EIRP CONTOURS. IN PRACTICE THERE IS CONSIDERABLE LOCAL VARIATION WITHIN EACH HEMISPHERE.

design, designated INTELSAT IVA, which increased transponder count per satellite to 20 by employing partial frequency re-use. The two large paraboloids were retained in modified form, now offset-fed by clusters of feed horns to generate shaped beams in eastern and western hemispheres. These **"hemispheric"** beams are half-global in shape, named because they illuminate half the visible sphere of the Earth - they are not themselves hemispherical.

The hemispheric beams are shaped so as to give adequate east/west (spatial) isolation (27 dB minimum) for frequency re-use. Transponder/beam switching is more complex than on the INTELSAT IV series and eight pairs of transponders are selectable either between full hemisphere and half-hemisphere spot or between spot and global beams. As before, four transponders are tied to global beam operation without re-use (Fig. 3).

Simplified hemispheric beam contours are shown in Figs. 15 and 16 for Atlantic and Indian Ocean INTELSAT IVA satellites. Only **beam-edge** levels are specified by Intelsat, and the real-world contours within the beams may be more complex than those shown, with localized islands of higher EIRP. I have also added estimated contours beyond the nominal 26 dBW beam-edge, to indicate larger terminal reception possibilities subject to accept **co-channel interference** levels from the opposite hemisphere.

INTELSAT IVA global beams are essentially the same as those from INTELSAT IV satellites, at 22 dBW saturated beam-edge EIRP. The spot beams obtained by illuminating half of a hemispheric region have a nominal minimum beam-edge value of 29 dBW.

Five satellites of this class are operational.

INTELSAT V

A totally different spacecraft design was selected for the 1980s. Ford Aerospace's bird is 3-axis stabilized, with four offset paraboloid reflectors as well as global horns. Beam shaping is further developed from the IVA series, and additional spectrum re-use is obtained at C-Band by **polarization as well as beam isolation**. All previous INTELSAT 4 GHz downlinks employed exclusively **right-hand circular** polarization. INTELSAT V added four 80 MHz zone beam transponders in each hemisphere, polarized **left-hand circular**. This in addition to a more complete re-use between east and west hemispheres in right-hand circular slots 1 - 9, reconfigured to include four "80 MHz" transponders (sometimes defined as 3 x 72 MHz plus 1 x 77 MHz) and one 36 MHz transponder, per hemisphere. Transponders 10, 11 and 12 remain on global beam with no re-use, though 12 is extended to 41 MHz bandwidth, to utilize what was hitherto a dead band between 4193 and 4200 MHz (see Fig. 3).

The sixteen transponders of 80 MHz (two-channel) width are equipped with higher power TWTAs to give 29 dBW hemispheric beam-edge EIRP, but TWTA power is traded for antenna gain in the zone beams, retaining 29 dBW at beam-edge. The global 36 (and 41 MHz) transponders are also equipped with the more powerful 8.5-watt TWTAs, increasing global beam-edge EIRP to a nominal 23.5 dBW (real-world closer to 24 dBW). An optional switch connects the 80 MHz transponder slot 7 - 8 to global beam, giving 26.5 dBW.

Through the **four-fold spectrum use**, the C-Band capacity is greater than 37 equivalent 36-MHz transponders, per satellite. Plus INTELSAT V also includes a **Ku-Band** communications payload with two "80 MHz" channels (one 77 MHz plus one 72 MHz) and one 241 MHz channel in each of two linearly polarized spot beams - frequency re-use again (see Fig. 5). There is also the facility to "cross-strap" 6 GHz uplinks into 11 GHz downlink channels and 14 GHz uplinks into 4 GHz downlinks.

So total capacity is up to 2137 MHz in **27 transponders**, equivalent to over **57 standard full-transponder TV channels**, with spectrum to spare. And there is more. Future INTELSAT V flights will include a Maritime Communications System (MCS) package cross-strapped C- and L-Band, to replace MARISAT in support of the MARECS satellites in the INMARSAT system.

As of summer 1982, four INTELSAT V satellites are operational, with a fifth due for launch as we go to press. The higher capacity birds have taken over Primary Path traffic in Atlantic and Indian Ocean regions, and a major program of earth terminal retro-fitting is in progress to double communications capacity via the cross-polarized zone beams. Heavy traffic nations in Europe and the Middle East are adding Ku-Band standard "C" stations to their existing standard "A" facilities.

Fig. 17 shows the Earth as seen by the Atlantic Primary bird over 24.5°W. This type of projection is useful to the satellite antenna designer as it shows the **true cross-sectional shape** of his beams. The scales at top and right represent degrees of beam angle, and can be related to the subsatellite point at center. I have shown here the nominal beam-edge contours for an INTELSAT V at this location. The global beam-edge is coincident with the Earth horizon, on this projection. The solid line curves are the 11 GHz spot beams, centered on the US heavy route station at Etam, WV, and on western Europe. Specification beam-edge EIRPs are actually 44.4 dBW for the west spot and 41.1 dBW for east - I have here estimated the 44 and 41 dBW contours for convenience. Fig. 24 shows the Atlantic east spot pattern over Europe. The dashed line curves on Fig. 17 are the left-hand circular zone beams and the dotted lines the right-hand circular hemispheric beams.

The foreshortening of regions near the Earth horizon makes this view none too clear at these points, so in Fig. 18 I've transferred the contours to our Armadillo map. The global pattern is shown separately in Fig. 19, while Fig. 20 reveals the alternative zone beam shapes and spot beam boresights for the Indian Ocean region. All these are **beam-edge specification** EIRP levels, and are generally exceeded by about 0.5 dB, but occasionally as much as 2.0 dB, at beginning of life.

THE GLOBAL SYSTEM

Since the oceans are the great natural barriers to wide-band communications, it was across the world's three major ocean regions that INTELSAT first provided cir-

INTELSAT V ATLANTIC PRIMARY, 24·5° W

FIGURE 17.

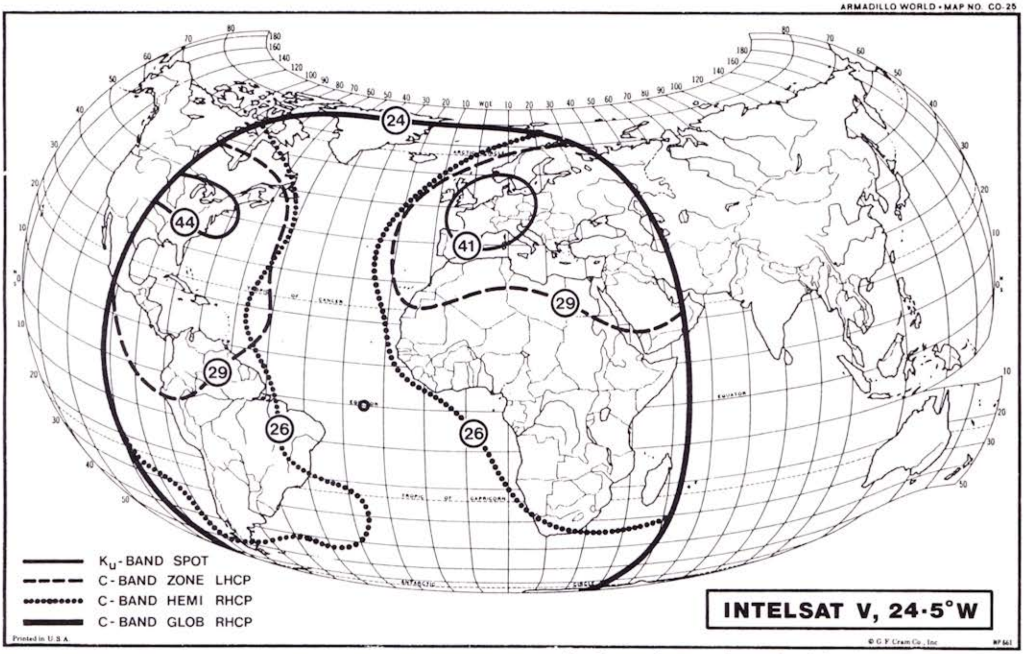


FIGURE 18.

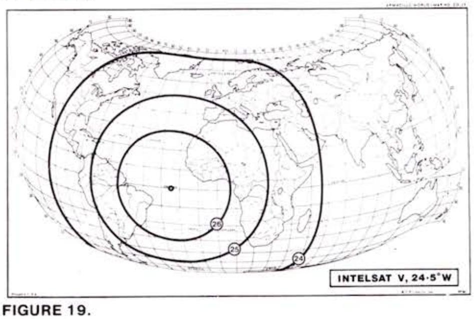


FIGURE 19.

TV monitor at rear of antenna provides spectrum analyzer display to aid satellite location.

cuits. From clusters above the Atlantic, Indian and Pacific Oceans Intelsat can offer global telecommunication service to any nation which opts for membership. The Atlantic has the lion's share of satellites, since the greatest demand is within this region, encompassing Europe, the Middle East, Africa, North, Central and South America and the Caribbean. INTELSAT is now beginning to expand in **inter-region** locations at 53°W, 1°W and 148°W, to avoid double-hop interconnections and to extend lease capacity.

Fig. 21 shows visibility limits (and hence global beam-edges) for the present Atlantic grouping. The letters indicate, from the west, the following birds:

A	53°W	INTELSAT IV F7	Special lease service, Central America
B	34.5°W	INTELSAT IVA F4	Atlantic Major Path 1
C	27.5°W	INTELSAT V F2	Reserve for Atlantic Primary and M.P.1
D	24.5°W	INTELSAT V F3	Atlantic Primary
E	21.5°W	INTELSAT IVA F2	Domestic Lease and reserve for M.P.2
F	18.5°W	INTELSAT IVA F1	Atlantic Major Path 2
G	1°W	INTELSAT IV F2	Residual Spare

INTELSAT Atlantic spare locations at present vacant are 4°W and 29.5°W.

In the Indian Ocean region the picture is less complex:

63°E	INTELSAT V F4	Indian Ocean Primary
63°E	INTELSAT IVA F6	Spare
60°E	INTELSAT V F1	Indian Ocean Major Path/ Operational Reserve
60°E	INTELSAT IVA F3	Spare

The two spare INTELSAT IVA satellites are expected to take up new locations soon, when transponder by transponder handover to the INTELSAT V satellites is completed. F6 will move to the Pacific. Indian Ocean spare locations at present vacant: 57°E, 66°E.

For the Pacific Ocean region:

174°E	INTELSAT IV F1	Pacific Ocean Primary
179°E	INTELSAT IV F8	Pacific Ocean Reserve

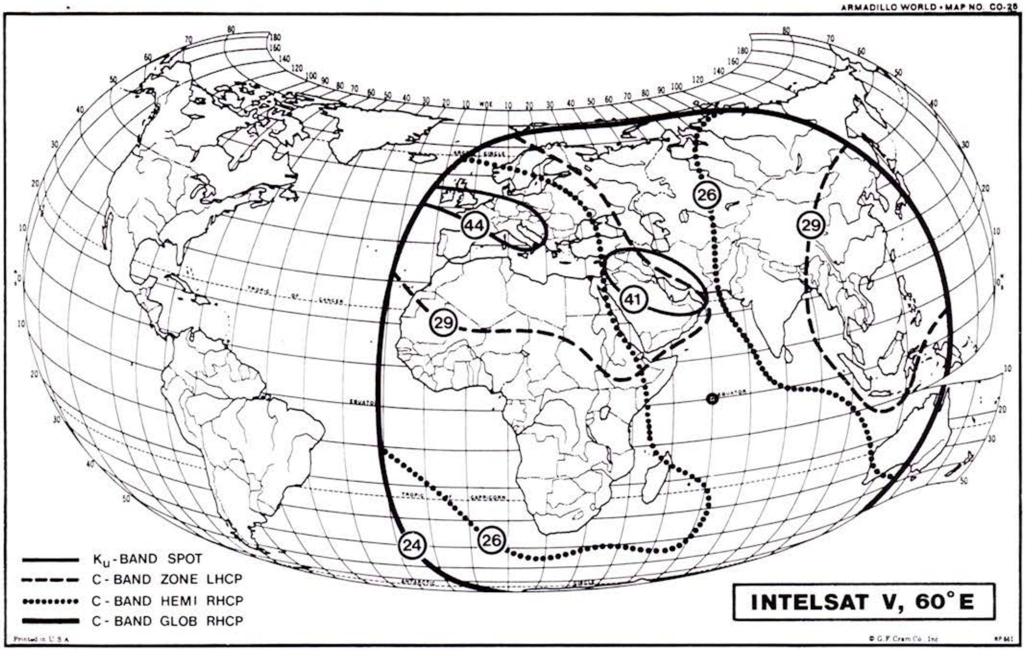


FIGURE 20.

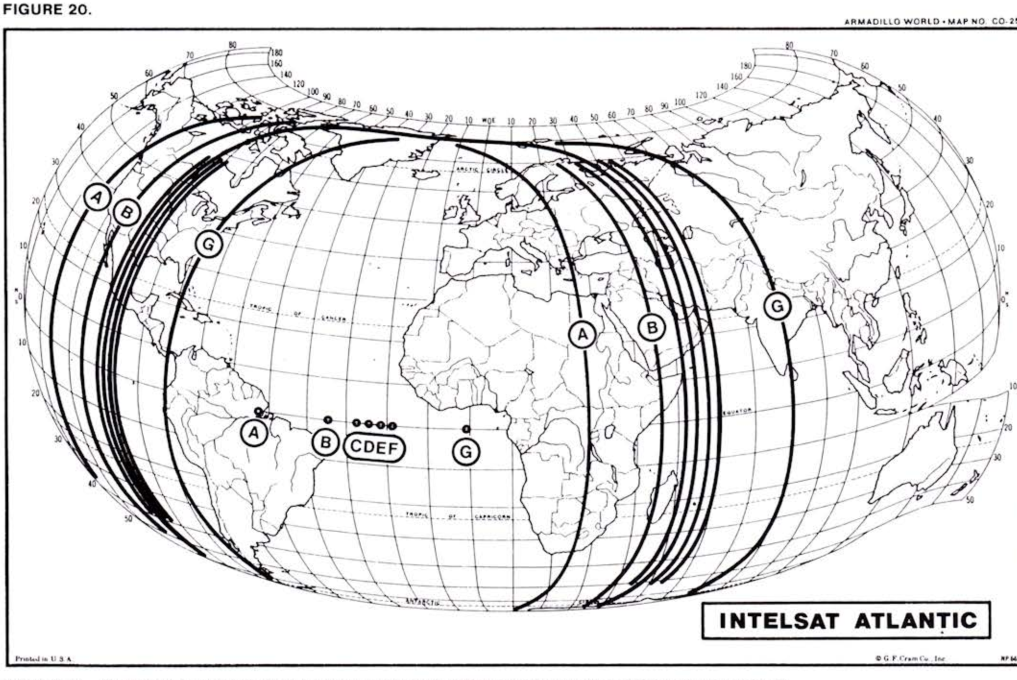
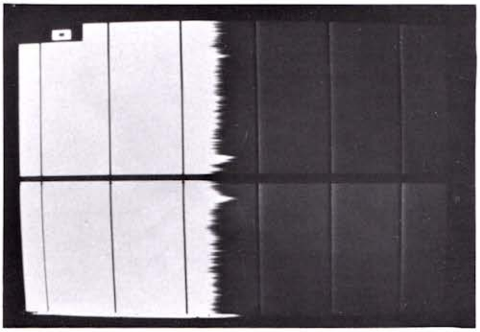


FIGURE 21. VISIBILITY LIMITS (GLOBAL BEAM-EDGE) FOR THE SEVEN ATLANTIC OCEAN INTELSATS.

Three INTELSATs are in drift orbits, on their way to new locations:

INTELSAT IV F3	over 49°W. drifting rapidly westwards	as of early August 1982
INTELSAT IV F4	over 56°W. drifting eastwards	
INTELSAT IV F5	over 67°W. drifting eastwards	



Telemetry beacons are the only clue to the presence of an inactive INTELSAT, or one in transit.

In all cases the assignment of satellites to orbital locations is fluid, and some details may have changed by the time you read this.

Fig. 22 reveals the Armadillo map's limitation in its coverage of the Pacific. INTELSAT IV global beam contours are drawn, together with ideal **saturated** footprint levels for the spot beam serving the Australian lease services, boresighted near Alice Springs. The global beam is well seen in USA and Canada, west of the Rockies.

CLASSES OF TV SERVICE

Television is only one form of telecommunications traffic to use the global system. The majority of INTELSAT carriers are FM modulated by **frequency division multiplex** (FDM) telephony, each carrier being allocated transponder bandwidth and power according to capacity, from 24 telephony channels in 2.5 MHz up to 1092 channels in 36 MHz. So a single transponder may contain a variety of carriers of different levels and bandwidths, from various sources and heading for various destinations. In general, as might be expected, the big ones carry traffic between the major centres, though within an FDM stack there may well be a group of channels headed for a relatively minor target. This **frequency division multiple access** (FDMA) is the reason INTELSAT terminals have to conform to mandatory standards. Uplink EIRP must be controlled within narrow limits to avoid destructive intermodulation effects.

Television used to be easy by comparison. It always went **global beam**, and usually on transponder 12 [24]. Saturated global beam EIRPs were no problem for standard "A" and "B" terminals, and video SNRs in excess of 50 dB were obtained. Plan 1 in Fig. 23 shows 36 MHz wide full-transponder TV (video), as is still the standard for most domestic satellite systems. To obtain increased margin against threshold in standard "B" stations a 25

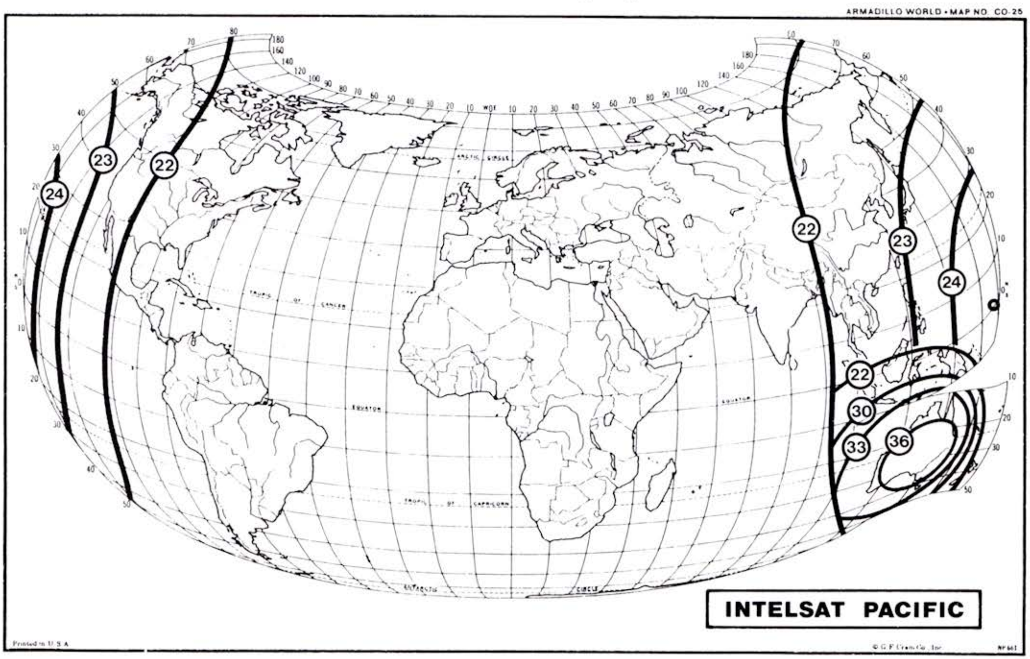


FIGURE 22.

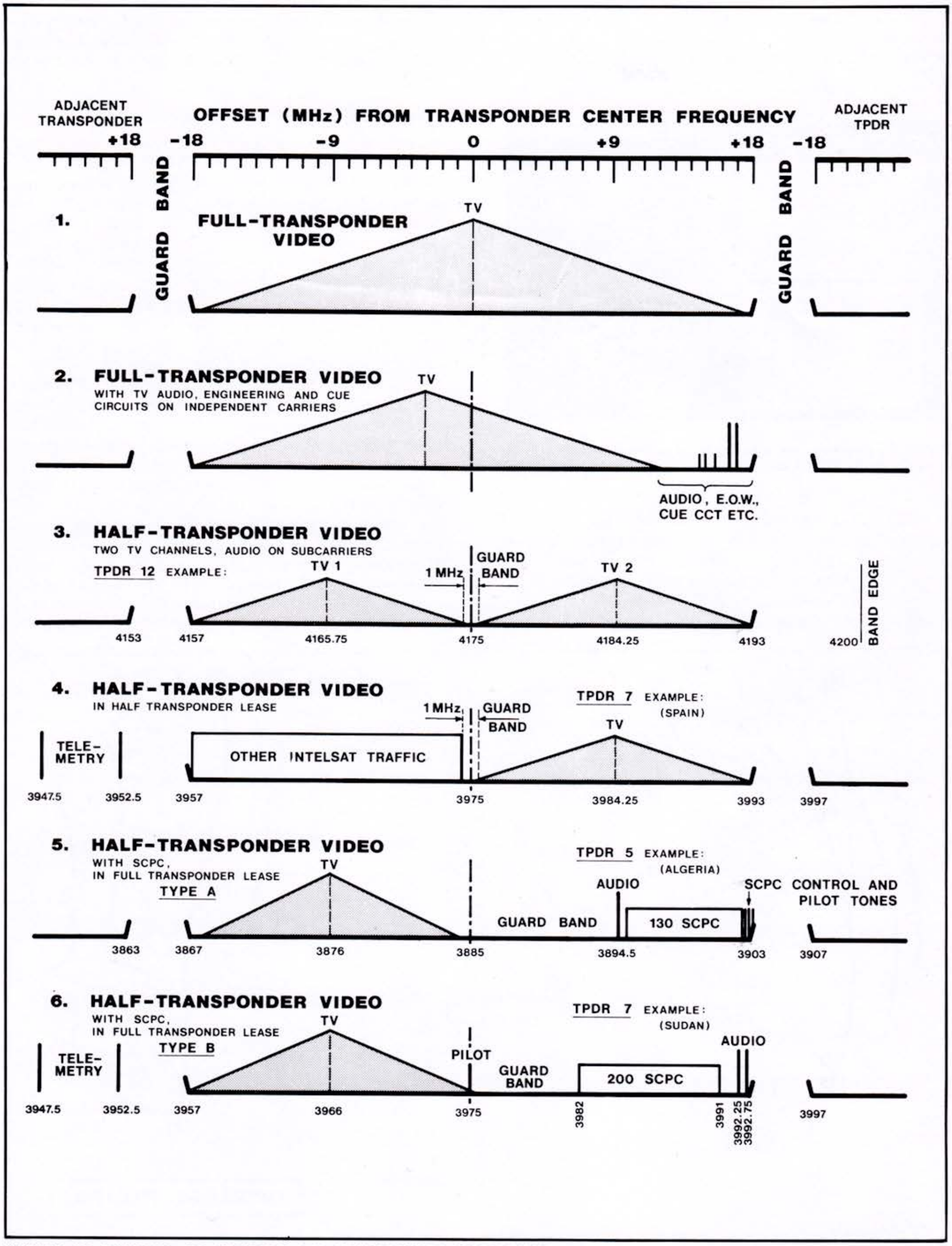


FIGURE 23. CLASSES OF INTELSAT TV TRANSPONDER OCCUPANCY.

MHz bandwidth was sometimes used, but this still amounted to full-transponder TV. Even with a bandwidth as low as 17.5 MHz (half-transponder value), full transponder power is available.

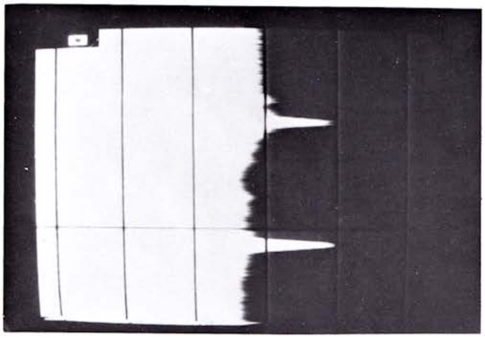
An alternative plan (2 in Fig. 23) offset the TV carrier frequency by some 3 MHz from channel center, so permitting sound carriers and engineering communication circuits to be fitted in at the opposite edge of the transponder on independent carriers. The penalty here was the need to **backoff** the TV carrier from transponder saturation, to minimize intermods.

"OCCASIONAL" TV

In those early days all INTELSAT TV was of an occasional nature. A major news story - usually disastrous: floods, earthquake, war, assassination. Live coverage of events capturing the public imagination - the Apollo moon landings; international sports - World Cup soccer or the Olympic Games.

Full transponder was more than good enough for the global system, and with increasing demand for international TV service, INTELSAT eventually standardized on **half-transponder** format. Here (Fig. 23, plan 3) each TV video channel is allocated almost half the transponder bandwidth and **rather less than half** the transponder power. Again, to control intermodulation products the two carriers have to be **"backed off"** from TWT saturation into the more or less linear portion of the transfer characteristic. This amounts to a "throttling back" of the EIRP not just by the 3 dB resulting from power sharing, but by an **extra 2 to 6 dB**, dependent on the TWTA characteristics. In a global beam of 22 dBW saturated beam-edge, half-transponder TV with FM/FDM telephony in the other half, TV beam-edge EIRP is 22 minus 3 dB for power sharing, minus 4.5 dB backoff, equals 14.5 dBW. Receiver noise bandwidth is reduced also, with IF filter bandwidths of 17.5 or 15.75 MHz being standard for half-transponder TV, but to clear threshold still demands a standard "A" terminal, achieving video SNRs in the upper 40s. Figures are a bit more promising at beam center with at least 17.5 dBW EIRP, and the use of an INTELSAT V global beam raises this to 19.5 dBW. With TV carriers in both halves of the transponder, intermod constraints can be relaxed a little, but output backoff is still between 3 and 5 dB. In practice levels vary and a range of EIRPs is seen within dual half-transponder TV working, between about 14 and 17 dBW, INTELSAT IV or IVA global beam edge (17 to 20 dBW center) or up to 19 dBW INTELSAT V global beam edge (22 dBW center). Every once in a while an uplink will turn on at such a level that it saturates the TWTA with its half-transponder video, robbing the other TV channel of power. Such errors are normally short-lived, with an interaction of around 1 dB being more normal, and the transponder-sharing works remarkably well considering the multiplicity of terminals capable of access.

This mode of dual half-transponder TV is used throughout the global system, generally in transponder 12 [23/24]. Today "occasional" means well-nigh continuously, day and night. The unpredictability of source and content makes it perhaps the most fascinating channel of all to watch, though the low EIRP levels make that a difficult pursuit. Reception techniques are discussed later in this section.



TV screen spectrum analyzer display shows two half-transponder TV signals in tpdr slot 12 [24] of Atlantic Major Path 1 INTELSAT.

Referring back to Fig. 3, I have listed half-transponder TV frequencies for reference. Precise center frequencies may vary by 1 MHz or so in some cases, just to confuse the unwary. Accompanying sound is now almost universally on a subcarrier at either 6.60 or 6.65 MHz, although until recently a carrier in transponder 10 [20] was used in the Pacific Ocean region. On some transmissions the audio is a **clean feed** of effects or international sound, and local commentary channels are established over telephony circuits elsewhere.

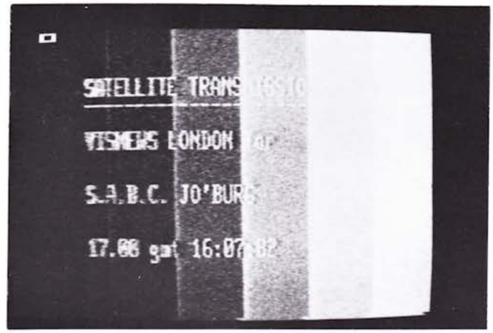
OCCASIONAL- AND MORE REGULAR FEEDS

The transponder 12 [23/24] traffic is not entirely unpredictable. After a day or two watching the two half transponders on each of the birds in a regional cluster, regular patterns emerge.

The feeds which recur on a daily basis are generally **news packages** for international exchange. Organizations like Visnews and UPITN specialize in collecting film and video items of immediate news stories and redistributing them to broadcast outlets worldwide. UPITN is a consortium of United Press, America's ABC Television and the UK's Independent Television News. They collect and distribute their news compilations over the Eurovision (EBU) and Intervision (OIRT) terrestrial networks and via the global satellite system.

UPITN's first offering of the day is DSS/E, the daily satellite service to Europe, at 1400 hrs London time (local clock time is kept summer and winter, so it would not be correct to say GMT). DSS/E goes out on the Atlantic Primary INTELSAT at 24.5°W, in 625-line PAL format. The Soviet earth station at Dubna near Moscow receives this feed, converts it to SECAM color and puts it back up on the Statsionar-4 GORIZONT at 14°W, tpdr 10 [9] for the use of Intersputnik members including Cuba. Sound is limited to natural effects with the occasional commentary in English. The transmission contains ten or twelve short but pertinent news items, immediate stories from Europe and usually the previous day's from the world. The British "speaking clock" can be heard at low level between

What happened to Buenas Noches?



items.

At 2050 London time DSS/A (Atlantic) out of London hits the Major Path 1 INTELSAT bound for destinations in North and South America. The UPITN compilation is followed closely by a whole series of news feeds for ABC, NBC, CBS, CNN and Brazil's TV Globo. The whole shooting match runs for over an hour each day, in 525-line NTSC format.

While DSS/A is still heading west over the Atlantic, DSS/W begins out of Washington, DC, at 1600 local time. This is uplinked from the US west coast (after a hop on WESTAR) to the Pacific Primary INTELSAT at 174°E for use in Australia and the Far East.

Then at 1800 New York time the UPITN operation in that city sends DSS/L to Latin-America via the Atlantic Primary bird. This runs for 30 minutes and contains unilateral feeds for TV Globo of Brazil. UPITN operates a further feed, DSS/P (Pacific) out of New York which is widely used throughout the Pacific Ocean region. Uplink is from Jamesburg, California, to the Primary satellite.

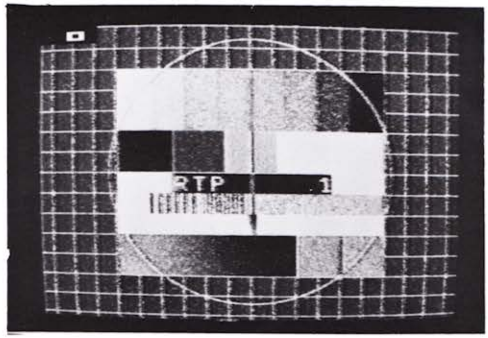
And the Indian Ocean doesn't escape. UPITN uplinks the whole of ITN London's nightly "News at Ten" in PAL 625-line format, for use in Australian TV's morning show.

That is just one organization. In the Atlantic region alone several other regular newsfeeds are seen. Visnews produce an Atlantic package out of London at 2145 local time, NTSC for North American consumption, and a special feed for the South African Broadcasting Corporation in Johannesburg in PAL at 1800 London time. The latter runs for ten minutes, but the transatlantic feed contains unilaterals for all the US networks, and lasts typically one hour. Both these on the Primary Path.

Eurovision in Brussels collects a news compilation live from European sources at noon each day in Belgium, and birds it in original PAL/SECAM mix via the Primary

(24.5°W) while an NTSC version flies in parallel on Major Path 2 (18.5°W). A second EVN assemblage goes out at 1700 local time on the Primary satellite. Both these are 30 minutes in length.

TVE Spain airs its news at 2110 Madrid time, for 15 minutes of NTSC to Latin-America via Primary, and RTP Portugal relays its full mid-evening news, Tele Jornal, to the Azores in PAL color at 2130 Lisbon time each evening on the same satellite.



The 2030 news from Portugal is birded to the Azores via the Atlantic Primary INTELSAT.

Cable News Network has a daily shot at 1900 Central European Time on the Primary for ten minutes of NTSC from Rome to Atlanta, and the ABC News operation in London regularly fills 45 minutes of satellite time with 5 minutes of news material, in NTSC via 24.5°W beginning around 2230 London time.

France Regions 3 puts out a 30 to 60 minute news transmission at 1600 local time from Paris to French-speaking territories in the Atlantic Primary region, 625 lines SECAM, with simultaneous transmission via SYMPHONIE's western spot beam.

All the times given refer to the start of the actual news material. Typically there is a pre-transmission line-up period of between 5 and 20 minutes, during which a pulse and bar, window, multiburst, staircase or color bar waveform with tone or spoken ident may be uplinked, with or without visual identification. All these feeds are in transponder 12 [23/24], upper or lower half-transponder format, with subcarrier audio at either 6.60 or 6.65 MHz. Choice of upper or lower half appears to be fairly arbitrary, and an already-commenced occasional feed will displace a regular feed from its normal half. Scheduling has to take care that transmissions finish on time, to avoid the regular traffic being bumped off completely. GMT is used throughout the global system, and care has to be taken

EXAMPLE OF REGULAR DAILY NEWS TRANSMISSIONS,

INTELSAT ATLANTIC OCEAN REGION

All transmissions global half-transponder TV in slot 12, all times U.K. local (U.S. Eastern + 5 hours).

PRIMARY PATH, 24.5°W:

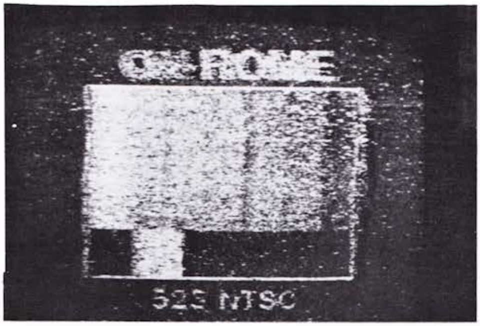
TIME	SYSTEM	SOURCE and CONTENT
1100	PAL/SECAM	EUROVISION BRUSSELS European news exchange (NTSC on MP-2)
1130	NTSC	US NETWORKS news feeds from LONDON
1400	PAL	UPITN DSS/E news service from LONDON (SECAM on GORIZONT)
1500	SECAM	FR3 news package from PARIS (also on SYMPHONIE)
1600	PAL/SECAM	EUROVISION BRUSSELS European news exchange
1800	NTSC	Cable News Network ROME to ATLANTA
1800	PAL	VISNEWS for SABC Johannesburg from LONDON
2010	NTSC	TVE news package from MADRID
2030	PAL	RTP Tele-Jornal (news) from LISBON
2145	NTSC	VISNEWS Atlantic package from LONDON (incl. US network feeds)
2300	NTSC	UPITN DSS/L news service from NEW YORK (incl. TV GLOBO)

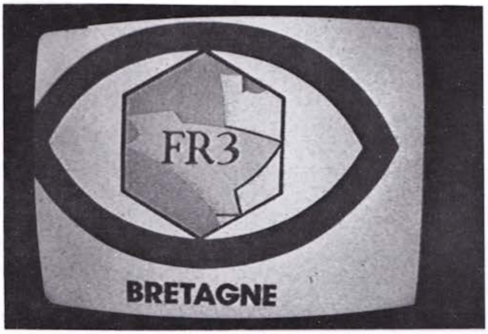
MAJOR PATH 1, 34.5°W:

1930	NTSC	NBC Sports from NEW YORK (Saturdays)
2050	NTSC	UPITN DSS/A News service from LONDON (incl. US networks & TV GLOBO)

MAJOR PATH 2, 18.5°W:

1100	NTSC	EUROVISION BRUSSELS European news exchange
1930	NTSC	ABC Sports from NEW YORK (Saturdays)
2230	NTSC	ABC News feeds from LONDON





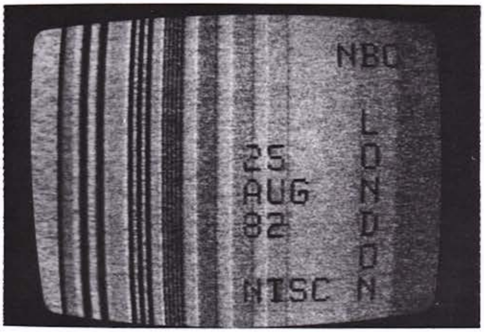
with adjustments for local summer time occurring on different dates from one country to another.

Other sources while less regular are not entirely unexpected when they pop up in the transponder. During major world sports events a second transponder is often set aside for distribution, so as not to clog up the global works for occasional TV. So just as the 1978 World Cup soccer series in Argentina made use of Major Path transponder 8 [15/16], so Spain in 1982 was much in evidence on transponder 1 [1] on the Major Path 2 satellite.

Major news stories make heavy demands on global resources, though distribution on the large scale can look inefficient. Beirut, Lebanon was the scene of much bombing and shelling during the week in July when I updated my INTELSAT observations, and at times an almost continuous flow of on-the-spot ENG reports were radiating from that corner of the world. NBC Tel Aviv, Herzliya Studios Israel, Capital Studios Jerusalem, CNN Jerusalem, BBC Tel Aviv, Iraqi TV Baghdad, Damascus Pool and others were on the screen several times per day on the Atlantic Primary and Major Path satellites, sometimes on two channels simultaneously and often the same report would appear 7 or 8 times on different feeds, in the course of the day. An IRA bombing in London kept the London ABC News studio on the bird for over two hours one afternoon - the locations and uplinks that appear are a strong indication of where the news is being made. COMSAT's Etam earth station sets an excellent example with on-screen display of source and destination during the line-up period.

In early April 1982, INTELSAT records were broken when 572 international TV transmissions were made around the globe in the one week period 12 - 18 April. The Falklands/Malvinas crisis was a major contributor to the heavy traffic at this time. Previous record was held by a week in January 1981, when 540 transmissions occurred, at the time of the US Presidential Inauguration and the release of the Iranian hostages.

US network feeds form the bulk of occasional (more or less unpredictable) TV traffic, particularly on the London to New York path, in NTSC color. There are certain



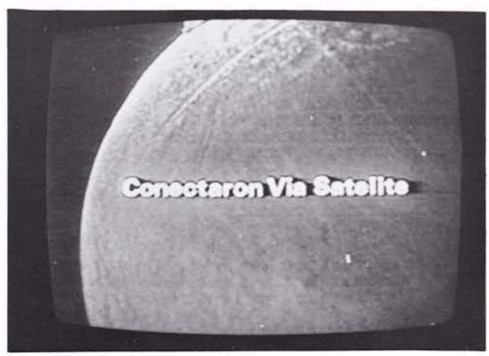
preferred times and places (e.g., 11 a.m. London time on the Atlantic Primary, when the morning's news from England can line up for the American breakfast programs) but they can show at all times of the day or night.

On Saturday afternoons in the USA, network sports often find their way onto the Atlantic (and Pacific) Intelsats. NBC is almost a regular on 34.5°W between 1430 and 1800 eastern time, and ABC has been showing recently on 18.5°W. Both these feeds are complete with American commercials, NTSC color.

A spectacular "occasional" use of the Atlantic system occurs monthly (?) on a Saturday or Sunday evening. TVE Spain transmits its overseas magazine program "300 millones" in NTSC to Spanish-speaking outlets all over the American continent. To do this it uses the Primary and Major Path 1 birds simultaneously, and as if that wasn't enough Dubna receives it, SECAMs it and GORIZONTs it on zone beam transponder 9 [6].

INTERNATIONAL LEASE SERVICE

A recently introduced tariff category provides for **full-**



time international TV transmission via INTELSAT.

Network feeds for US personnel overseas are promised 24 hours per day beginning in 1983, and dependent on transponder and beam configuration they could be in great demand for small terminal reception. One report suggests a **full global transponder** on the 1°W spare INTELSAT IV will carry the service to American forces in Europe and the western Indian Ocean, the NTSC material being uplinked from Andover, Maine. The satellite currently on station in that slot (F2) is a real old-timer, has very limited north/south stationkeeping (inclination at present 3.9°) and would seem unsuited for service to small terminals. But at least one of the INTELSAT IVs now drifting eastward is heading for that slot, so we look forward to developments around the New Year.

Another possibility is Ted Turner's Cable News Network, out of Atlanta, GA. Already this is planned for 24 hour per day Pacific Ocean region transmission beginning 1983 for use by Australia and Japan, and a European link is being sought for a later date.

Ted, Anglophile yachtsman and "Captain Outrageous" intends to make a version of his service available live to Europe, first via INTELSAT and perhaps later on a European satellite. Speaking at a TV festival in Edinburgh, August 1982, he said "I intend to put it up there and if the Government doesn't like it, you can **bootleg** with receiving dishes in your garden, risking being locked up in the Tower, burnt at the stake or garrotted."

Should Ted opt (availability permitting) for an INTELSAT IV full transponder spot beam, those garden dishes could be as small as the 3-meter home terminals in use throughout the USA. A permanent service to Cable TV outlets would downlink at 11 GHz.

DOMESTIC LEASE SERVICE

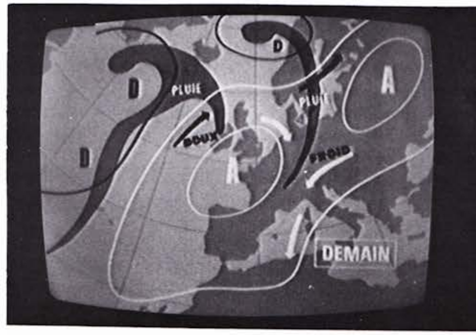
In recent years a great deal of INTELSAT capacity has been leased out to member nations for their own internal use, either within a country, or to link oveseas territories with the mainland. This is a fast-growing area with developing countries aspiring to their own communication satellite systems, but initially leasing space segment from INTELSAT to establish their operations. Total leases now approach the equivalent of two full INTELSAT IV birds.

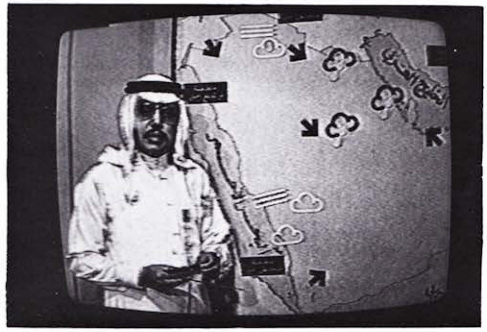
Satellite capacity is leased in units of full, half or quarter transponders, in global, hemispheric or spot beams, on a pre-emptible or non-pre-emptible basis. Pre-emptible capacity is normally leased for a five-year period, but short term leases of as little as three months are available. In the event of satellite failure, the more expensive non-pre-emptible leases are restored with the same priority as the international service.

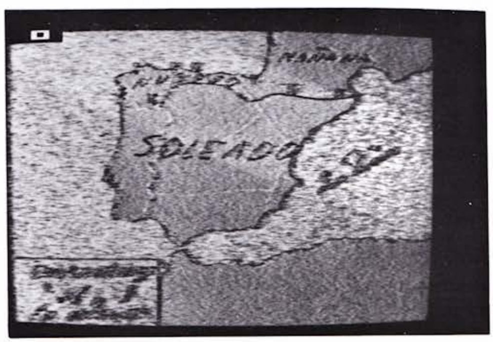
Quarter transponder (9 MHz) leases are widely used for domestic lease telephony and telegraphy but will not support normal video, so we shall examine here only the half and full transponder situations.

Spain operates a typical half-transponder TV lease, with the requirement to make mainland (Madrid) television available to the citizens of her overseas territory, the Canary Islands. Initially Television Espanola used INTELSAT "occasional TV" capacity to bring a nightly news program from Madrid, via the Buitrago (Spain) and Aguimes (Canaries) standard "A" terminals. As time went by the number of live transmissions increased, and in 1976 Spain took the decision to lease full time half of a global beam transponder on the Atlantic Major Path satellite, at that time an INTELSAT IV, to transmit the country's main network, TVE-1.

Since then the Major Path 1 slot has acquired an INTELSAT IVA, and Spain has accepted transfer to an **eastern hemispheric** beam which gives her a higher available EIRP, although with standard "A" terminals at both ends this is not required. Fig. 23 plan 4 shows the Spanish lease. A submarine cable provides telephonic connection between the Canaries and the mainland, so only TV is required by satellite, supported by a half







High pressure in France, sunny in Spain and wet in Saudi Arabia.

transponder lease. The other half of the transponder therefore carries regular FM/FDM INTELSAT traffic. Spain leases the upper half of transponder 7, which I have called 7B [14]. TV sound is multiplexed with the video signal by allowing the audio to frequency modulate a subcarrier at 6.6 MHz.

The transponder output backoff amounts to some 6 dB, giving a hemispheric beam-edge EIRP of 17 dBW, so favored locations within the beam will see as much as 22 dW, perhaps 3 dB above the average global half-transponder occasional TV carrier at the average location. This is overkill as far as the Canaries are concerned, but it offers opportunities for us, being on the limit of a 6-meter terminal's capability, as we shall see.

Comparable with Spain is the Brazilian lease. The national TV service, TV Globo, is distributed from Rio to provincial cities using **western hemispheric** transponder 11B (upper half) [22] of the reserve INTELSAT IVA at 21.5°W (reports Bob Behar). Program sound is believed to be likewise on a 6.6 MHz subcarrier and the beam-edge EIRP is on a par with that of the Spanish lease. Compatible with good 6-meter TVRO hardware in the more favorable parts of the footprint (Fig. 15 west, contours minus 7 to 9 dB). A feed of Brazilian TV has now appeared on global transponder 6 [11], with 5.8 MHz audio subcarrier.

The Pacific Ocean INTELSAT region is not without domestic lease services. In late 1979 Australia commenced lease of global half transponder 5A [9] on the Pacific Primary INTELSAT IV F8 over 174°E, for internal TV relay. Both government (ABC) and commercial feeds have been seen on this channel. Audio on 6.5 MHz subcarrier. Half-transponder TV in a half transponder lease, on INTELSAT IV global beam, demands a standard "A" terminal at each end of the link (EIRP order of 14.5 dBW beam edge). This suggests an east/west link between program centers.

Subsequently, when East Malaysia's lease of transponder 3 [5] expired (or moved elsewhere?). Australia took over the full transponder, boresighted the western spot beam near Alice Springs, Northern Territory (Fig.22), and commenced fulltime 2-channel TV service to the Australian outback, dual half-transponder occupancy (Fig. 23, plan 3). Both channels are provided by the Australian Broadcasting Commission, one uplinked from Moree in the east and one from Carnarvon in the west. Program sound is again on 6.5 MHz subcarrier. Information from Peter Duddy of Vanuatu, South Pacific.

Now boresight EIRP on the INTELSAT IV spot beams is in the region of 37 dBW at saturation. With dual half-transponder TV, carrier power is down by 3 dB for sharing, and then perhaps 4 dB backoff is required, giving a beam-center EIRP of around 30 dBW (Fig. 22 contours minus 7 dB). That puts most of outback Australia within the 28 dBW contour, requiring typically a 4.5 meter terminal.

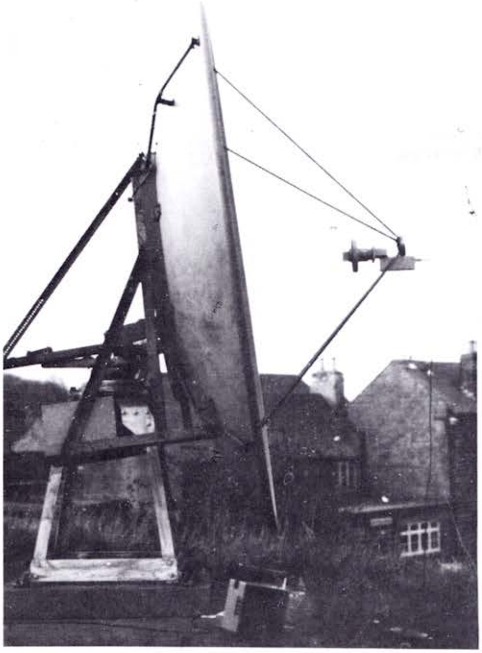
ENHANCED HALF-TRANSPONDER (A)

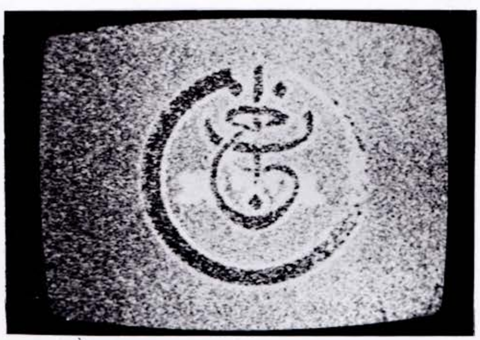
The very first INTELSAT domestic lease began in 1975, when GTE International commissioned a total of 14 earth stations for the government of Algeria. A fifteenth was added later. The system was inaugurated on global beam via an INTELSAT III satellite over the Indian Ocean and subsequently transferred to an INTELSAT IV global transponder at 1°W. It permitted expansion of the Algerian telecommunications network by connecting the main station (standard "A") at Lakhdaria near Algiers with 14 communities across the Atlas mountains and out over the Sahara. From the start the system was engineered for television distribution as well as multiple-access telephony and telex service using demand-assigned **single channel per carrier** (SCPC) circuits. All stations were to have message transmit/receive capability, while TV was handled by the remote terminals in a receive-only mode. To build and maintain terrestrial microwave relays across hundreds of miles of desert would have been prohibitively expensive, and a domestic satellite system, albeit with leased space segment, was the only way Algeria could provide national television service to these outlying communities.

The need to deliver adequate television picture quality from a global beam transponder, possibly at a low elevation angle, was the major factor in determining the size (and hence cost) of the remote stations. A video signal to noise objective of 45 dB was set, and it was concluded that this could be achieved with remote terminals of 11 meters aperture, conforming to INTELSAT standard "B" (G/T 31.7 dB/K), provided **rather more than half** the transponder power could be made available to the television signal. As part of the trade-off between noise and distortion, an overdeviation factor of 8.7 dB was applied to the video modulation, using a receive bandwidth of 15.75 MHz. To maximize power in the TV carrier, the spectrum plan of Fig. 23 (5) was adopted. The SCPC message channels were moved up to the HF end of the transponder allocation, leaving a **9 MHz guard band** into which the principal intermodulation products would fall, avoiding harmful interference. The TV sound channel (I like to speak of sound and vision, or image, channels - audio and video are the actual baseband modulating signal waveforms within those channels) is transmitted itself as a form of SCPC: the audio signal modulates an independent **wide band FM** carrier just below (in frequency) the block of message channels. This plan I have called Enhanced Half-Transponder, type A, for want of a better name. Enhanced because the carrier can be some 2 to 3 dB higher in level than in regular half-transponder format.

The SCPC channels are voice-activated, providing a 2.5-times advantage in power sharing, which is realized as a greater number of channels than could be accommodated if they were all on power full-time. 130 FM channels are configured within the available 8 MHz bandwidth, and are assigned on request through a two-way pair of polling control channels, situated above the message block. On the extreme edge of the transponder channel is transmitted an unmodulated **pilot tone** which is used as a frequency reference in the SCPC equipment, to cancel frequency dr anywhere in the system.

Since the shift of INTELSAT TV traffic from 1°W, the Algerian domestic lease has operated on the Indian Ocean reserve INTELSAT IVA at 60°E, in western emispheric transponder 5 [9]. This has increased beam-edge EIRP by 3 to 4 dB, giving improved C/N margin at the Algerian desert stations (although the look angle is lower) and making the ervice receivable over a wide area of Europe and Africa, with a 6-meter class TVRO (TV EIRP about 22 dBW hemispheric beam-edge, or about 4 dB below the saturation contours of Fig. 16, western hemisphere).





My 8-foot antenna struggles with an eight-degree elevation angle and a neighbor's tree to scratch a signal from Algeria via the Indian Ocean INTELSAT.

ENHANCED HALF-TRANSPONDER (B)

A second type of occupancy for half-transponder TV in a full transponder lease is shown at Fig. 23 (6). This is the plan used by the Sudan's domestic lease, but a similar pattern is employed by Zaire, Niger, Oman and Morocco.

Sudan leases transponder 7 [13] on the Atlantic reserve INTELSAT IVA at 21.5°W. Here the overdeviation factor is even greater (12 dB) and the video receiver bandwidth standard half-transponder, 17.5 MHz. 200 SCPC message channels are incorporated on 45 kHz centers in a 9 MHz block, with EIRP around -5 dBW per carrier. Message IF bandwidth is 36 kHz. Pilot tone is situated mid-transponder and the two wideband FM audio channels are at upper channel edge, each of +6 dBW EIRP in 240 kHz bandwidth. Two channels are provided to permit sound radio as well as TV sound distribution, but at present both carry the TV program audio. Sudan's video is among the strongest of the INTELSAT IVA enhanced half-transponder services, at an estimated maximum of 23 dBW hemispheric beam-edge. As with most of the long-term leases, they were **originally global** but **transferred to hemispheric** in recent years, to make the most of available INTELSAT IVA capacity. Sudan's ground segment was supplied 1976/78 by the Harris Corporation. The master station is at Umm Haraz, near Khartoum and the site of Sudan's standard "A" terminal, and there are 13 eleven-meter standard "B" remote terminals in regional centers.

Of the other "enhanced half-transponder" operators, Oman is interesting in that it has retained global beam operation on account of its geographical location - on the visibility limit of the Atlantic cluster and directly between the two hemispheric beams of the Indian Ocean group. But its position within the 1 dB global contour of the 60°W bird is a slight advantage over its previous home, on INTELSAT IV at 1°W.

Morocco too has a jolly operation on the reserve INTELSAT V at 27.5°W. Here the lease is a virtual full transponder 3 [5], realized as half the 80 MHz transponder slot 3-4, on hemispheric beam. And it's the hottest half-transponder here in England at an estimated 24 dBW beam-edge. That could put it as high as 29 dBW towards Morocco. Good for a quiet 4.5-meter terminal with threshold extension, over most of the hemispheric footprint.

Other INTELSAT V equivalent half-transponder leases are those of Colombia and Peru. These countries have each leased a quarter transponder for SCPC/FM telephony since late 1978, but in 1982 commenced TV operation on the reserve INTELSAT V at 27.5°W. The western hemispheric beams of this bird cannot be received at my own location, and full details are not yet available, but Bob Behar of Florida reports that Colombia is in tpdr 1 [1] and Peru in tpdr 2 or 3 [4]. Subcarrier audio audio has been observed, but **unrelated** to the TV program content. So far Bob has been unable to find the program sound for these services, which we would logically expect to be SCPC wideband FM at the opposite channel edge, enhanced half-transponder fashion, so it may be in another transponder, perhaps along with the quarter transponder telephony, (or it may be transmitted in another form, such as a digital subcarrier, or sound-in-syncs.) If the Colombian and Peruvian leases **are** in enhanced half-transponder format, I would expect them to have Morocco-type EIRPs, in the range of 23-24 dBW beam-edge. If they are isolated equivalent half-transponder leases they will be closer to 19 or 20 dBW at edge of coverage, or 23 dBW in Florida.

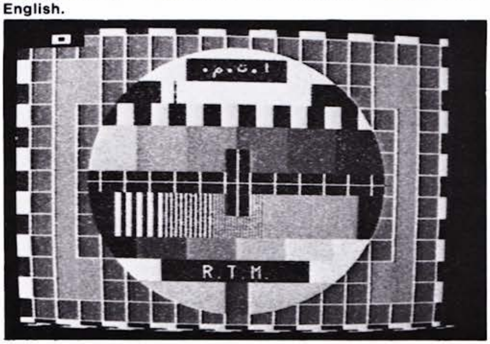
FULL-TIME INTELSAT DOMESTIC LEASE TV SERVICES

Country	Satellite	TPDR	Enhanced/ Half Full	Freq.	Freq/SC	Beam	EIRP, Beam-Edge	Video & Color System	Language	Program	Address
Saudi Arabia	IVA 21.5W	1[1]	F	3725	3900	E.Hemi	19-23	625 SECAM	Arab/Engl		Saudi Arabian Television, P. O. Box 570, Riyadh.
Niger	IVA 21.5W	3A[5]	E(B)	3795	3820	E.Hemi	18-20	625 SECAM	French	Tele-Sahel*	Office De Radiodiffusion Television Du Niger, B.P 309, Niamay.
Sudan	IVA 21.5W	7A[13]	E(B)	3965	3990	E.Hemi	21-23	625 PAL	Arab/Engl		Sudan Television Service, P. O. Box 1094, Omdurman.
Zaire	IVA 21.5W	9A[17]	E(B)	4045	4070	E.Hemi	18-20	625 SECAM	French	Tele Zaire	Office De Radiodiffusion Television Du Zaire, B.P. 3171, Kinshasa.
Brazil	IVA 21.5W	11B[22] ‡	H	4145	S/C 6.6	W.Hemi	18	525 PAL-M	Port	TV Globo	Rua Lopez Quintas 303, Jardim Botanico, 20000 Rio De Janeiro, RJ.
Colombia	V 27.5W	1A?[1]	H?	?	?	W.Hemi	?	525 NTSC	Spanish	Cadena-1	Inravision, Centro Administrativo Nacional, Via Eldorado, Bogota.
Peru	V 27.5W	2B?[4]	H?	?	?	W.Hemi	?	525 NTSC	Spanish	Enrad Peru	Empresa Nacional De Radiodifusion Del Peru, Jose Galvez 1040, Lima.
Morocco	V 27.5W	3A[5]	E(B)	3795	3820	E.Hemi	23-24	625 SECAM	Arab/Fren	RTM	Radiodiffusion Television Marocaine, 1 Rue Al Brihi, Rabat.
Argentina	V 27.5W	12[24]	F	4175	S/C 6.4	Glob	24	625 PAL-N	Spanish	ATC LS 82 Ca.7	Argentina Televisora Color, Figueroa Alcorta 2977, 1425 Buenos Aires.
Spain	IVA 34.5W	7B[14]	H	3985	S/C 6.65	E.Hemi	18	625 PAL	Spanish	TVE Cadena-1	Television Espanola, Apt De Correos 26002, Madrid 11.
Mexico	IV 53.0W	1[1]	?	?	S/C 5.8	W.Spot	34 or 27	525 NTSC	Spanish	XEW	Televisora De Guanajuata, Av Chapultepec 18, Mexico 1, DF.
Mexico	IV 53.0W	3[5]	?	?	S/C 5.8	W.Spot	34 or 27	525 NTSC	Spanish	TCM/TRM	Tele.Cultural De Mex. Torre De Communicaciones, Insurgentes Sur, Mex.Df.
Mexico	IV 53.0W	5[9]	?	?	S/C 5.8	W.Spot	34 or 27	525 NTSC	Spanish		Televisa, S.A., Edificio Televicentro, Chapultepec 18, MExico 7, Df.
Mexico	IV 53.0W	7[14]	?	?	?	W.Spot	34 or 27	525 NTSC	Spanish		
Australia	IV 174 E	3A[5]	H	3795	S/C 6.5	W.Spot	27	625 PAL	English	ABC	Australian Broadcasting Commission, P. O. Box 487, Sydney 2001.
Australia	IV 174 E	3B[5]	H	3815	S/C 6.5	W.Spot	27	625 PAL	English	ABC	
Australia	IV 174 E	5A[9]	H	3875	S/C 6.5	Glob	14.5	625 PAL	English	ABC	
Oman	IVA/V 60E	4A[7]	E(B)	3835	3860	Glob	16	625 PAL	Arabic		Radio Television Oman, P. O. Box 600, Muscat.
Algeria	IVA/V 60E	5A[9]	E(A)	3875	3900	W.Hemi	21	625 PAL	Arab/Fren	RTA	Radiodiffusion-Television Algerienne, 21 Blvd Des Martyrs, Alger.
Nigeria	IVA/V 60E	7B[14]	H	3985	?	W.Hemi	19	625 PAL	Engl/Afr	NTV Ch.10 Lagos	Nigeria TV Authority, 15 Awolowo Rd, SW Ikoyi (PMB 12036), Lagos.

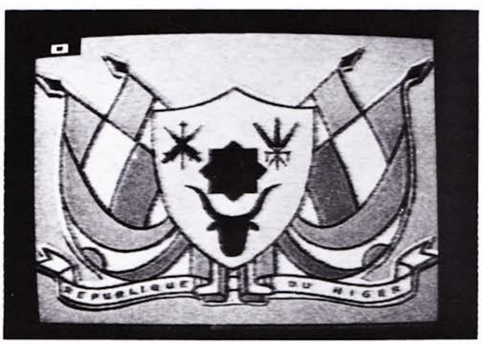
‡ Now in global tpdr. 6 [11] with 5.8 MHz subcarrier.

***Tele-Sahel Broadcasts 4 days per week.**

Sudan Television, like Saudi Arabia, transmits a news bulletin in English.



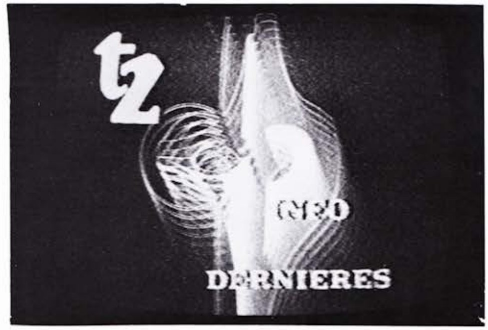
Morocco's INTELSAT V enhanced half-transponder is particularly strong.



Niger's 'Tele Sahel' transmits only four days per week.

That leaves us with Niger, Nigeria, Zaire and Malaysia. Nigeria leases three full transponders Indian Ocean hemispheric, and each has the capability for one TV channel, TV sound and radio channels, and 200 SCPC message channels on the basis of 40% utilization. TV video is currently on tpdr 7B [14].

Niger and Zaire operate enhanced half-transponder TV in east hemispheric channels 3A [5] and 9A [17]. The Niger program service, Tele Sahel, is on the air only **4 days per week** and deserves some kind of award for



Tele Zaire is predominantly French-speaking.

presentation. Niger's audio channel is the center one of three at the upper transponder edge, and Zaire's appears to be one of two, though their sound channel EIRP is particularly low. Both nations use only a small degree of "enhancement" of the video carrier (though deviation is high) possibly to accommodate more telephony channels, the lease now being hemispheric. Visual carrier EIRP is typically 3 to 4 dB below the Sudan datum, around the 18 dBW beam-edge level, although it has its good days.

Malaysia is reported by INTELSAT as operating a full transponder lease with enhanced half-transponder TV in the Pacific Ocean region, transponder 3 [5] on the Primary Path satellite at 174°E. Since Australia appears to have occupied this channel (reports do not all agree on which of the two Pacific birds), it is not known whether the Malaysian lease, which involved only two earth stations (13-meter) is still current elsewhere (such as the IOR). Observations please!

Uganda has definitely terminated her lease, as of 1979. Six 11-meter terminals were interconnected through a full global transponder, with enhanced half-transponder video. I wonder what they're doing now.

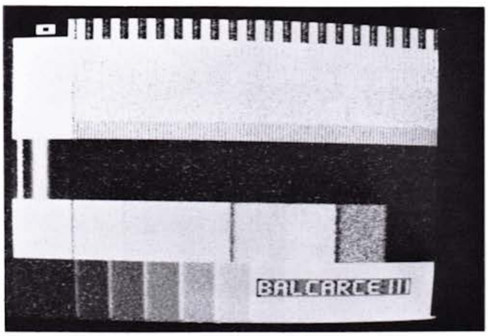
A recent report states that China is leasing Indian Ocean INTELSAT capacity on a trial basis, while preparing a Chinese domestic system for launch. It is not known how much space segment is involved but TV is understood to be transmitted.

FULL-TRANSPONDER VIDEO IN DOMESTIC LEASE

The big name here is Argentina. Beginning in 1982, the nation has taken a lease on global transponder 12 [24] on the reserve INTELSAT V, currently F2, over 27.5°W. This is operated in a **saturated full-transponder** video mode, with accompanying sound channel on a 6.4 MHz subcarrier. A second subcarrier at 5.8 MHz appears to be spare.

So over the whole Atlantic region, Argentina Televisora Color, LS 82 canal 7 of Buenos Aires is available at EIRP levels between 24 and 27 dBW (Fig. 19 approximates the coverage of the 27.5°W bird). Within the 1 dB-down contour (26 dBW real world) encompassing Brazil and

PAL-N, global full INTELSAT V transponder in Spanish, from Argentina.



Argentine uplink is Balcarce III, 24 hours per day.

West Africa, a well-engineered 4.5-meter terminal will provide watchable color pictures and audio, and a good 6-meter system is adequate for all but the lowest-elevation extremes of the visibility zone.

Also on full transponder is Saudi Arabia. The Saudis lease a total of 2¼ transponders for internal telecommunications, with a considerable amount of SCPC telephony passing through their fourteen 11-meter standard "B" terminals. On the Atlantic reserve satellite at 21.5°W they lease the whole of transponders 1 and 5, eastern hemispheric. Their system is unusual (and infuriating) in that the TV program sound does not accompany the image. Transponder 1 [1] carries the video information full-transponder, but in a backed-off mode. The 11-meter remote terminals require but a fraction of the 26 dBW (hemispheric beam-edge) power available, and the uplink power and transponder gain step are set to maintain EIRP around 6 dB below saturation. In practice the EIRP varies over a 3 or 4 dB range. Some days it is little stronger than a standard half-transponder occasional TV feed, others it is comparable with Sudan at around 22 dBW beam-edge - it seems to have declined markedly since the start of the hemispheric lease. Or they have a sick transponder.

Care is needed with a Saudi TVRO - it may look good on a standard 6-meter the day you install it, but your client

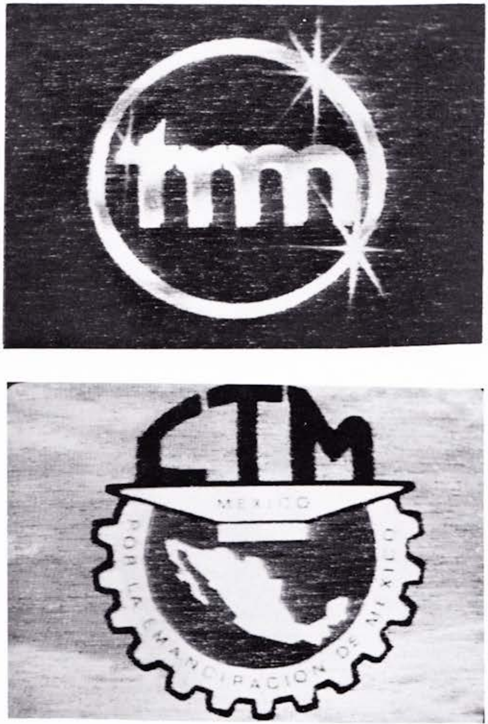
Saudi Arabia, not so much enhanced half-transponder as degraded full-transponder.

could be complaining of sparklies a few days later, when you find you should have specified a 7.5-meter system.

Transponder 1's stubborn refusal to deliver any audio has in the past been a puzzlement to some of those intrepid souls who travel the world putting in medium-to-large consumer grade TVROs. They find the world isn't just like America but bigger. No doubt Saudi could add a subcarrier to their video, just as they could increase the power to saturation if they chose to. But instead they make use of the fact that all their earth stations are also equipped for the message traffic in transponder 5 [9]. In amongst all that SCPC, at about 3900 MHz, they make a clearing and plant three wideband FM music channels, 500 kHz apart. Two are programs for radio broadcasting, and the third (actually the middle one) is the elusive TV sound. EIRP is in the region of 5 dBW per carrier.

And then there is Mexico. Something was clearly afoot when INTELSAT IV F3 was relocated to 53°W during 1981. Subsequently Mexico announced the start of a trial domestic TV lease operation and in early 1982 INTELSAT IV F7 hurtled (rather than drifted) from its Pacific spare location to 53°W, taking over service from F3 which then drifted rather more sedately eastwards (it has since begun a definite westward maneuver.) The assumption was that F3 was **unsuitable** for domestic service to small terminals because of its significant **orbital inclination**, which had increased from 0.4 to 0.9 degrees during the satellite's time at 53°W - there may be fuel constraints on closer north/south stationkeeping in the 11-year old F3.

Mexico requires high EIRP service in three or more channels. Assuming a boresight somewhere in the Yucatan region, the INTELSAT IV west spot beam will look something like Fig. 14, **at saturation**, and is available to transponders 1, 3, 5 and 7 [1, 5, 9 and 14]. Now the two reports which have reached me disagree on some fundamental points (like channel numbers), but it would appear that transponders 1, 3 and 5 [1, 5 and 9] are regularly programming to small terminals in Mexico via the spot beam. Tpdr 1 is reported to carry a variety of Mexican commercial programs, tpdr 3 [5] has been seen with US network stations KGTV or KFMB, San Diego, apparently without their knowledge or permission, and



Mexican leases on spot beam from INTELSAT 53°W. Photos Mark Long, The Book Publishing Company.

tpdr 5 [9] is variously reported as TRM (Television de la Republica de Mexico) educational channel or Televisa Cadena (XEW, Mexico City). Tpdr 7 [14] has also been seen on occasions. One source suggests tpdrs 1 [1] and 5 [9] are on **half transponder**, apparently with nothing in the other half, while the other quotes a signal level (equivalent to 29 - 30 dBW in Tennessee) perhaps a little low for full transponder, but rather too high for standard half-transponder TV, on the edge of the spot beam.

Potential spot-beam capacity available to Mexico is four full transponders, or eight half transponders, per INTELSAT IV at this location.

This looks like an interesting development in the domestic lease world, and may be setting precedents for other high EIRP spot-beam leases. Mexico could have her own domestic satellite system by 1985, so the INTELSAT operation may retain experimental status. Like the Pacific and South-East Asia regions, this is an area where we need more reports to clarify the situation. My thanks to Bob Behar of Hero Communications, Florida and Mark Long of The Book Publishing Company, Tennessee, for their reports on the 53°W bird.

INTELSAT Ku-BAND SERVICE

A total of 10 equivalent standard transponder bandwidths is allocated to each of two linearly polarized spot beams, the eastern beam placing a 41.1 dBW saturated beam-edge EIRP over Europe (Fig. 24). At beam center the EIRP exceeds 45 dBW over France, Germany, Switzerland, Austria, Czechoslovakia and parts of Spain, Italy and Poland.

Although they have been used for experiemental teleconferencing, these spot beams are at present underutilized, with some telephony traffic. I neither know of nor have seen any regular TV transmissions but, pending expansion of TDMA systems these beams **could** be used for three-channel TV relay to terminals as small as 1.8 meters in the central area, given the required stationkeeping accuracy. Europe generally has a considerable appetite for American TV, any American TV, and INTELSAT V could provide the channel for a **live feed to Cable outlets in Europe**, or even for retransmission via a future DBS.

LINE STANDARDS and COLOR SYSTEMS

All broadcast TV transmissions in the world are on either 405, 525, 625 or 819 lines. **All** satellite TV transmissions for eventual public consumption are either 525 or 625. So forget the other two - you'll never meet them. 525 lines, 60 fields/sec is the American standard, also used in Japan, and 625 lines, 50 fields per second is the European standard, used most other places. To convert between them requires a large and costly **time machine**, and is best left to the broadcasters.

525 lines generally goes with NTSC color on a 3.58 MHz subcarrier, except in Brazil where the 3.58 MHz subcarrier is modulated according to the PAL system (PAL-M). 625 lines generally goes with PAL or SECAM color on a subcarrier at (or near in the case of SECAM) 4.43 MHz. Again there's a South American exception: Argentina's 625-line system codes PAL on a 3.58 MHz subcarrier (PAL-N).

If you have a 525-line NTSC TV and come across a 625-line signal, for a start you'll not have color. You may feel the need to adjust the vertical hold, and when you do you'll find things look **tall and thin** - you need to find the TV's height (frame amplitude) control to make it look right. (Fig. 25).

Conversely to take 525 on a 625-line monitor, frame hold may require adjustment and amplitude will have to be increased. But to cope with the color system differences is not so easy. Figs. 26, 27 and 28 show principal color decoder differences. About the only place they agree is at the color difference level, where I and Q, U and V and (B-Y) and R-Y) are more or less equivalent. There's room here for a nice transcoder design, giving simplified conversions by recoding from the Y, U, V level. But I haven't got one.

If you're taking international satellite TV seriously you'll be getting a multistandard monitor. Barco (of Belgium) do a good range of **quadstandard** TVs that handle the three major world systems and terrestrial broadcast variations, plus the NTSC 4.43 standard that certain VCRs produce when replaying NTSC 3.58 tapes. Sony and JVC also have multistandard models, but be sure the NTSC you're getting is (American) **NTSC 3.58** and not just NTSC 4.43. Similarly you need to know it will handle **PAL 4.43** and not just the Brazilian or Argentine 3.58 version. The chances

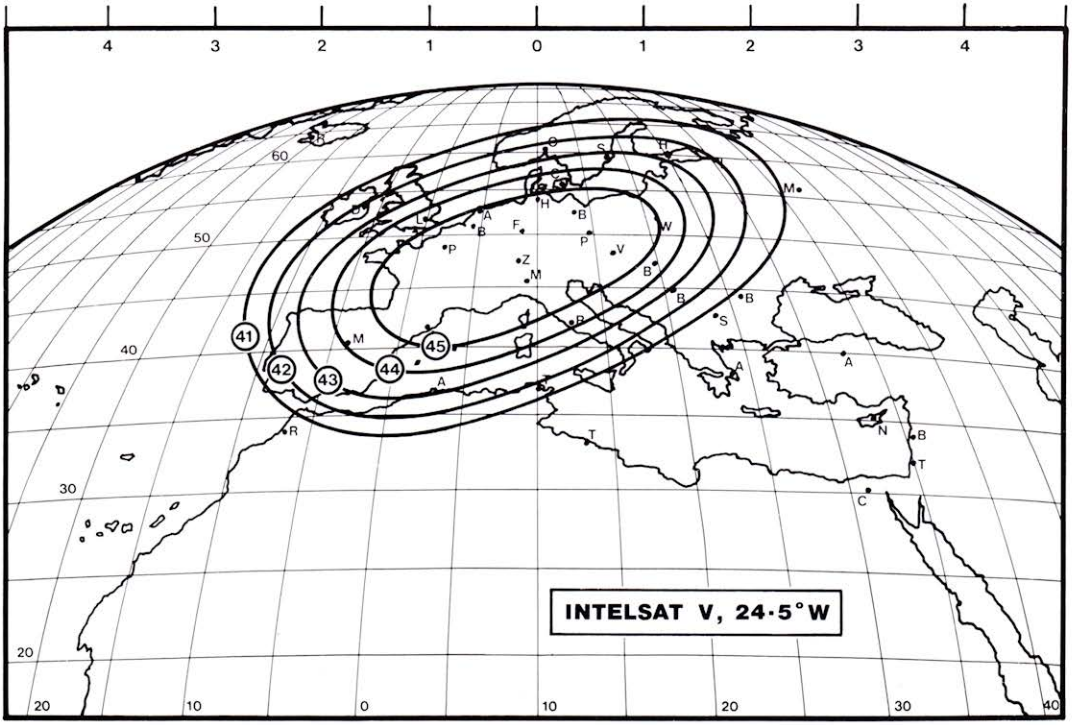


FIGURE 24.

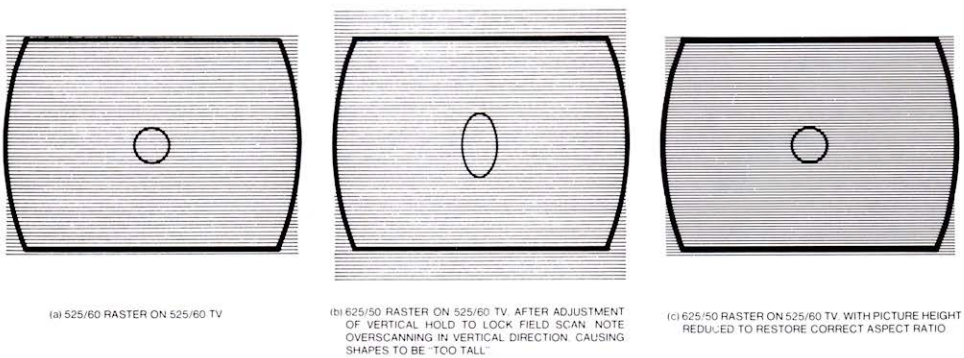


FIGURE 25. PICTURE HEIGHT NEEDS ADJUSTING WHEN RECEIVING A 625-LINE TRANSMISSION ON A 525-LINE SET.

TV STANDARDS, COLOR SYSTEMS AND TIME ZONES
for programming-originating countries mentioned in the text.
(Note: Newsfeeds are often on a different system to that of originating country.)

LOCAL TIME RELATIVE TO GMT

COUNTRY	LINES/ FIELDS	COLOR	STANDARD TIME	DAYLIGHT(Summer) TIME
ALGERIA	625/50	PAL	GMT	+1
ARGENTINA	625/50	PAL-N	-3	-3
AUSTRALIA	625/50	PAL	+8/10	+8/11
BRAZIL	525/60	PAL-M	-3	-3 (1)
BULGARIA	625/50	SECAM	+2	+3
CANADA	525/60	NTSC	-3½/8	-2½/7 (2)
CHINA	625/50	PAL	+8	+8
COLOMBIA	525/60	NTSC	-5	-5
CUBA	525/60	NTSC	-5	-4
CZECHOSLOVAKIA	625/50	SECAM	+1	+2
FRANCE	625/50	SECAM	+1	+2
GERMANY (FED)	625/50	PAL	+1	+2
GERMANY (DEM)	625/50	SECAM	+1	+2
HUNGARY	625/50	SECAM	+1	+2
INDIA	625/50	PAL	+5½	+5½
INDONESIA	625/50	PAL	+7	+7 (3)
ITALY	625/50	PAL	+1	+2
JAPAN	525.60	NTSC	+9	+9
LUXEMBOURG	625/50	PAL/SECAM	+1	+2
MALAYSIA	625/50	PAL	+7½	+7½
MEXICO	525/60	NTSC	-6	-6 (4)
MOROCCO	625/50	SECAM	GMT	GMT
NETHERLANDS	625/50	PAL	+1	+2
NIGER	625/50	SECAM	+1	+1
NIGERIA	625/50	PAL	+1	+1
OMAN	625/50	PAL	+4	+4
PERU	525/60	NTSC	-5	-5
PHILIPPINES	525/60	NTSC	+8	+8
POLAND	625/50	SECAM	+	+2
PORTUGAL	625/50	PAL	GMT	+1
ROMANIA	625/50	SECAM	+2	+3
SAUDI ARABIA	625/50	SECAM	+3	+3
SPAIN	625/50	PAL	+1	+2
SUDAN	625/50	PAL	+2	+2
SWEDEN	625/50	PAL	+1	+2
SWITZERLAND	625/50	PAL	+1	+2
UNITED KINGDOM	625/50	PAL	GMT	+1
U.S.A.	525/60	NTSC	-5/8	-4/7 (2)
USSR	625/50	SECAM	+3	+4 (5)
ZAIRE	625/50	SECAM	+1	+1 (6)

FOOTNOTES:

(1) Coastal Region

(2) Newfoundland	-3½	-2½
Atlantic	-4	-3
Eastern	-5	-4
Central	-6	-5
Mountain	-7	-6
Pacific	-8	-7

(3) Java, Bali, Sumatra
(4) Mexico City
(5) Moscow
(6) Kinshasa

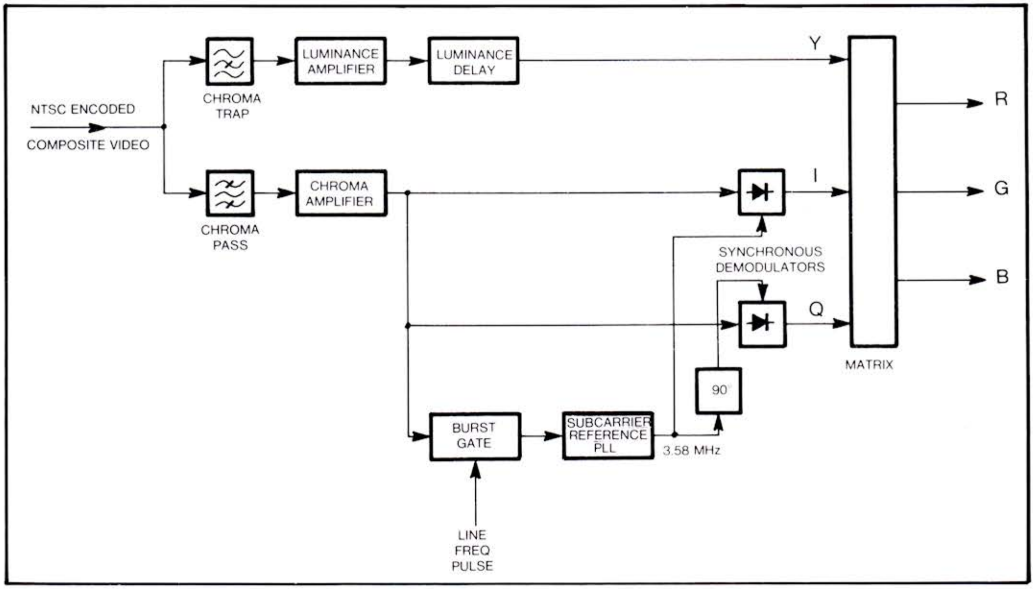


FIGURE 26. NTSC DECODER ELEMENTS

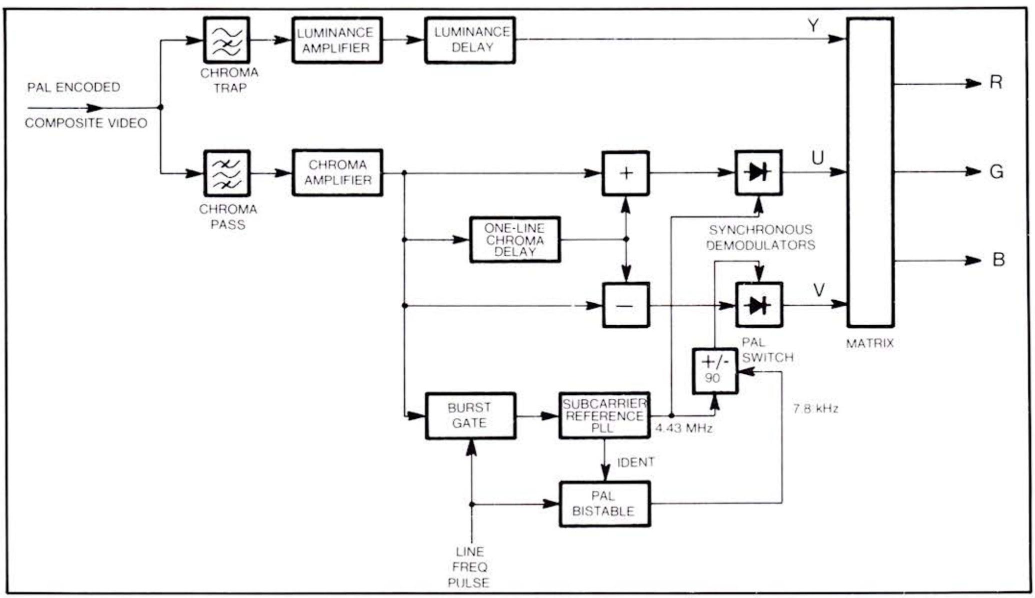


FIGURE 27. PAL DECODER ELEMENTS.

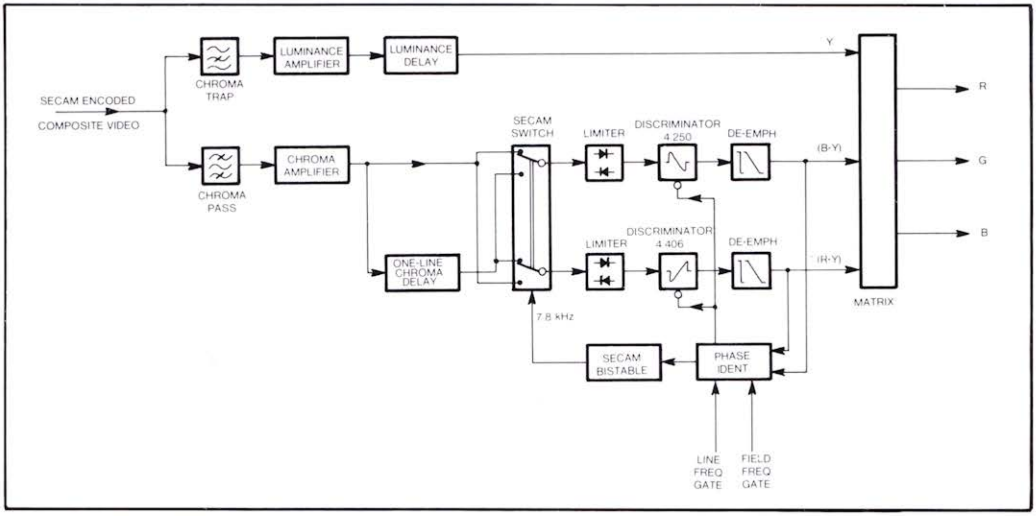
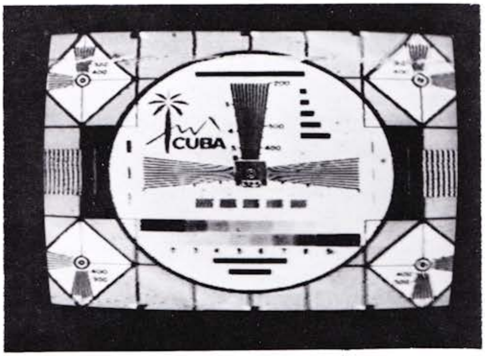
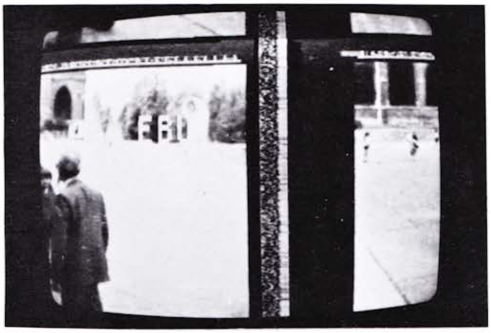


FIGURE 28. SECAM DECODER ELEMENTS.



A 525-line signal on a 625-line monitor gives a squat picture until you increase the frame amplitude.



This European PAL feed contains teletext data lines as well as digital sound-in-syncs.

are that modification will be required, even to a quad-standard set, to resolve color from Brazil or Argentina's domestic services.

Fig. 29 shows line frequency waveforms for the three major standards, plus the Orbita **pulse-width modulation** multiplex (e) and the BBC-designed digital **sound-in-syncs** (c) encountered within Europe. The Oak "Orion" encryption system uses a similar sound-in-syncs multiplex, and even the digits are scrambled! Sound-in-syncs anyway will not lock on unmodified monitors as the line (horizontal) sync pulse is effectively erased by the digital information. The field frequency waveforms of the two line standards (Fig. 30) show to scale the field period difference requiring vertical hold adjustment on a single-standard set.

We also need to consider the differences as they affect the video stages of our satellite receiver. Looking at the baseband spectra (Fig. 31) of 525 NTSC and 625 PAL (SECAM is similar) with typical audio subcarriers, it is evident that we need to **extend** the video band of a US home satellite receiver, as its normal roll-off commences even before PAL subcarrier frequency is reached (the shaded area represents color information). What is not so evident is the different **CCIR pre-emphasis** characteristic used on the two line standards. An incorrect network will result in overshoots or smearing on picture, and degraded video signal to noise ratio. The best way to tackle the differences is to fit filtering and de-emphasis for **both 525 and 625 lines**, and select by switch or relay according to the standard being received. Fig. 32 shows 625-line values for the video low-pass filter used in the Howard Terminal design and in many commercial

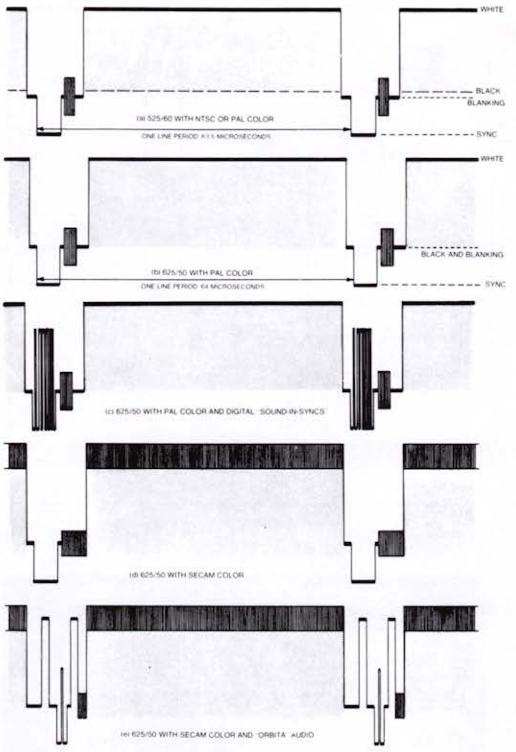


FIGURE 29. LINE FREQUENCY WAVEFORMS IN SATELLITE TELEVISION.

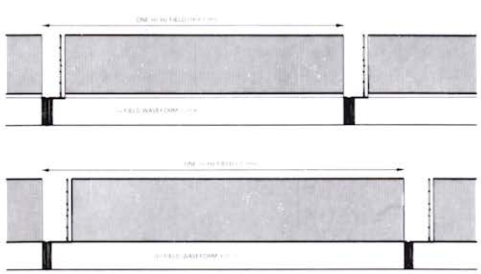


FIGURE 30. FIELD FREQUENCY WAVEFORMS IN SATELLITE TELEVISION.

receivers. These values are for 150 ohms characteristic impedance. Likewise, Fig. 33 gives de-emphasis network values for the two standards, in both 150- and 75-ohm impedances to suit most receivers. Microelectronics Technology Corporation of Palo Alto, CA, make a useful hybrid circuit which performs a switchable 525/625-line de-emphasis function, combined with video low-pass filtering.

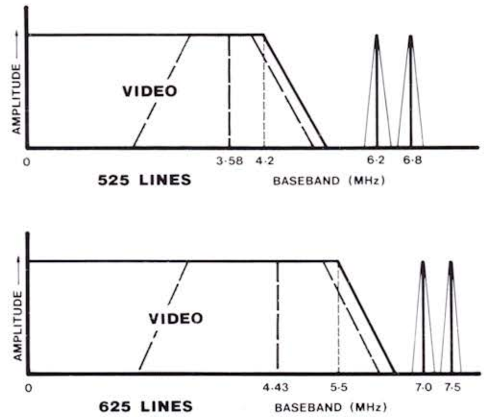


FIGURE 31. 525-LINE and 625-LINE BASEBAND SPECTRA, WITH TYPICAL SUBCARRIERS.

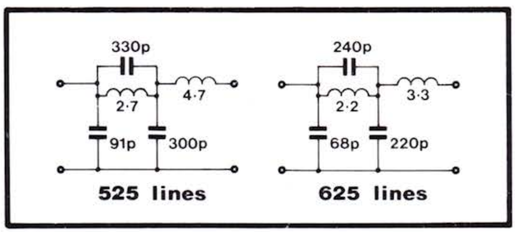


FIGURE 32. VIDEO LOW-PASS VALUES NEED ALTERATION FOR QUALITY 625-LINE RECEPTION - THESE VALUES ARE FOR A CHARACTERISTIC IMPEDANCE OF 150 OHMS.

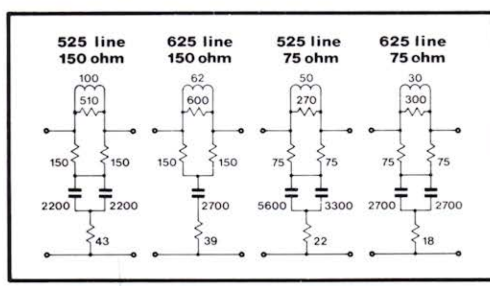


FIGURE 33. COMPONENT VALUES FOR CCIR DE-EMPHASIS NETWORK.

RECEIVER MODIFICATIONS FOR HALF-TRANSPONDER VIDEO

A standard receiver IF filter might be 30 MHz wide, centered on 70 MHz (Fig. 34). When confronted with dual half-transponder TV, both carriers being within its pass-band it will not differentiate between them, and demodulator output will be garbled. Tuning high or low will place one TV transmission at band center, but part of the other,

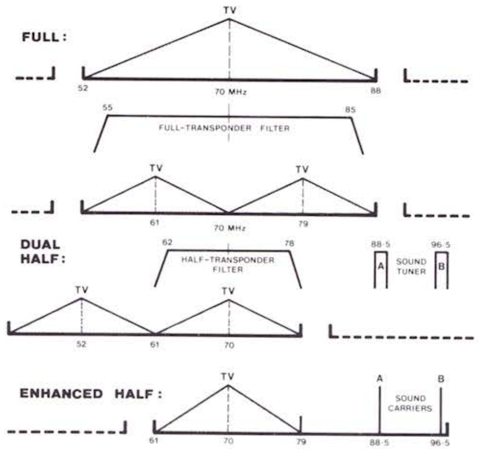


FIGURE 34. HALF-TRANSPONDER IF FILTERING IS A MUST FOR DUAL OR ENHANCED HALF-TRANSPONDER INTELSAT RECEPTION.

or whatever happens to be in the other half of the transponder or even the adjacent transponder, will also be passed causing degradations. Even in the absence of adjacent half transponder signals, the half-transponder TV signal will have to compete with a full transponder bandwidth of noise. In the worst case that means a 3 dB CNR loss. Even considering the difference between 25 MHz and 15 MHz filtering, the difference is 2.2 dB.

So half transponder filtering is essential if you're contemplating half-transponder TV reception, or you just throw away performance. Fig. 35 shows the 70 MHz IF filter found in a great many US home terminal receivers. It may well be the aftermath of the rush by various manufacturers around 1979-80 to get first generation TVRO receivers on the market. Tay Howard's STTI "Howard Terminal Manual" presented a design that the amateur could reproduce and that worked well, and it must have saved a lot of small companies the expense of design engineers and development labs.

Howard designed his filter to be easy to align for any bandwidth between 18 and 30 MHz. Whether the filter in your radio looks like this or not, provided it's 70 MHz and 75 ohms you can use this design for a second, switched filter, set for half-transponder bandwidth. The numbers of turns shown are for inductors close-wound on quarter-inch or so coil forms with slugs. American Coilcraft or Japanese Toko make suitable coils. The MP (mid pass) coil is tuned to 70 MHz, HP and LP (high and low pass) are tuned 2 MHz inside nominal bandwidth limits, each end, and HN and LN (high and low notches) are each tuned 7.5 MHz outside the nominal bandwidth limit. The overall response is then trimmed to be substantially flat, using a sweep generator. It should be **possible** to set up a 16 MHz bandwidth by aligning HN to 85.5 MHz, HP to 76 MHz, MP to 70 MHz, LP to 64 MHz and LN to 54.5 MHz, though I haven't tried.

For experimental below-threshold reception it is occasionally useful to go even narrower than this. My original video demodulator (pre-GORIZONT) used the Signetics NE561B phase-locked loop IC. This was not capable of the wideband performance of Howard's NE564 (see photos) but when operated below limiting it had the useful property of adjusting its tracking range according to the input signal level. Except where stated, all off-screen photos in this book are from reception with my own 8-foot (2.4 meter) 120°K installation. So if you're wondering how I've got any pictures at all from those INTELSAT global half-transponders, I can tell you that

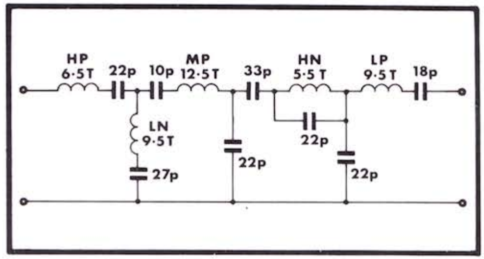
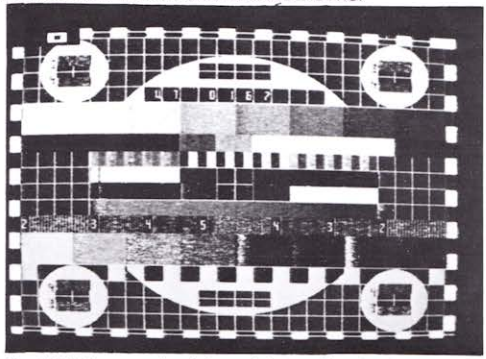
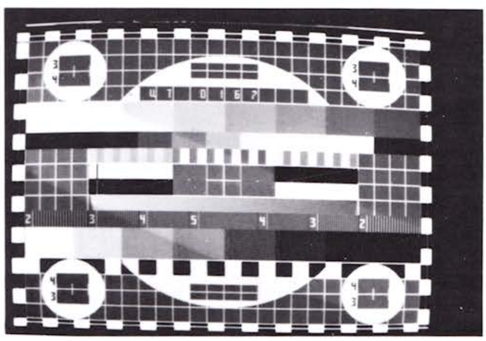


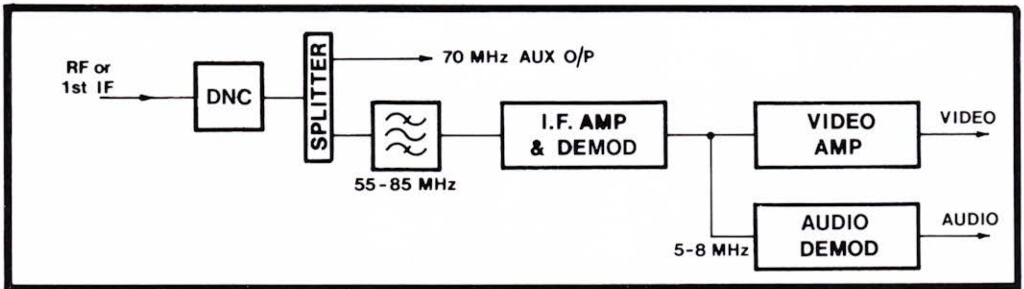
FIGURE 35. TAY HOWARD'S IF FILTER CAN BE ALIGNED FOR FULL OR HALF TRANSPONDER BANDWIDTHS.



The NE561 narrow-band demodulator will make the best of a weak signal, but tracking range is inadequate for quality demodulation when signals are good.



This is the same transmission through the NE564 demodulator.



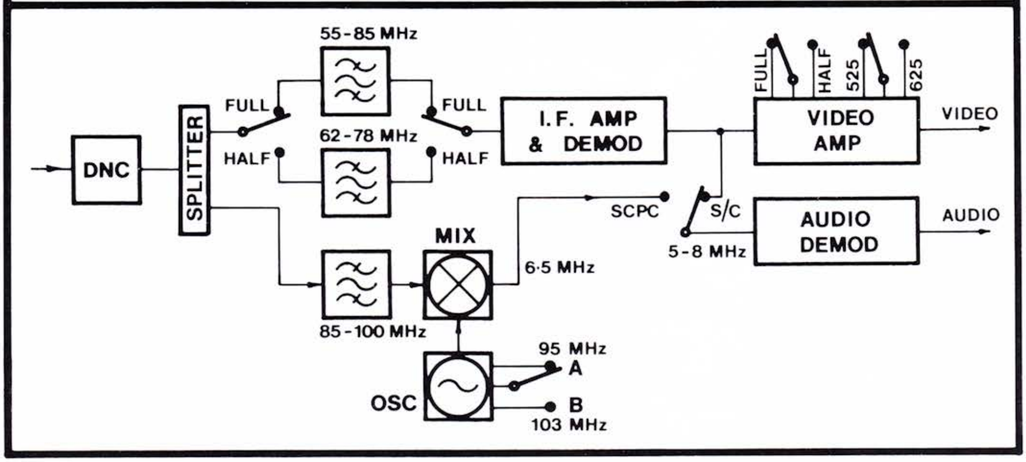


FIGURE 36. STANDARD RECEIVER WITH EXTRA 70 MHz IF TAKE-OFF.

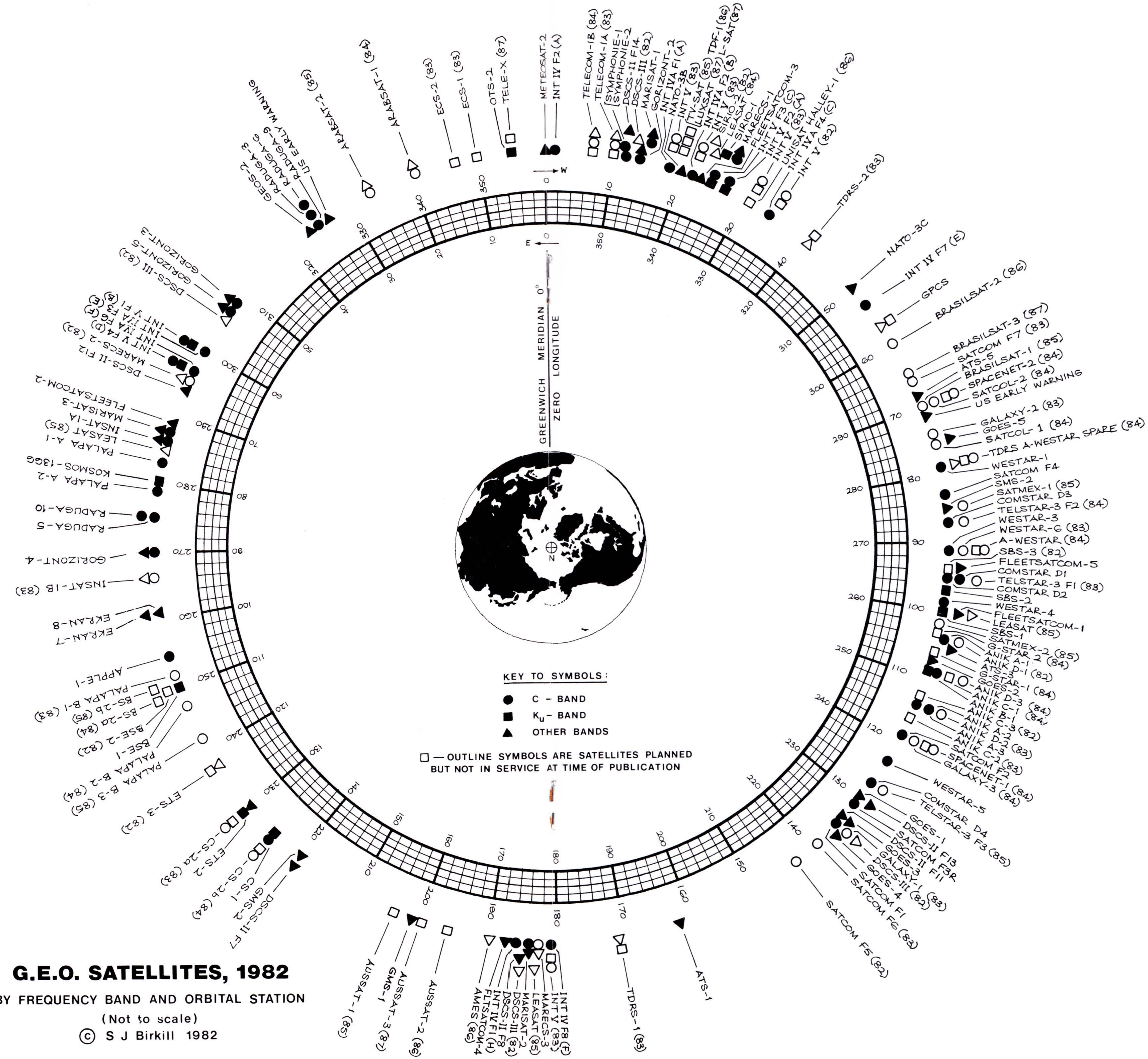
FIGURE 37. SWITCH-SELECTED MODES WILL PROVIDE FLEXIBILITY FOR INTELSAT OR DOMESTIC SATELLITE RECEPTION. AFC CIRCUITRY MUST BE WELL ENGINEERED.

some of those shots show reception in an IF bandwidth of **3 MHz**! The NE 561B is now obsolete, but the similar NE560B is still obtainable. I haven't included a circuit here because the aim of this book is to get you some good color pictures, not noisy black and white ones.

To attach such a demodulator for testing is a useful facility, or to connect an FM radio for SCPC audio demodulation. Fig. 36 shows a matched 70 MHz **splitter** incorporated before the receiver's IF filter. This can be a 3 dB coupler or simply a resistive 6 dB power divider, terminating in a rear panel jack. Some receivers may already have such an auxiliary IF output fitted.

Fig. 37 shows a receiver modified for INTELSAT as well as domsat reception. Full and half transponder filters are switch-selectable, and video gain is also switched to compensate for the differing levels out of the demodulator. De-emphasis and low-pass filter networks are switched for 525 or 625-line reception, and provision is made for SCPC TV sound. The IF splitter now feeds, via a bandpass filter, a balanced mixer to convert the SCPC audio down into the frequency range (at least 5 to 8 MHz) of the standard tunable subcarrier audio demodulator. Looking back to Fig. 34, bottom line, when the enhanced half-transponder vision carrier is centered in the half transponder filter, the sound carriers are near to 88.5 MHz (format A) or 96.5 MHz (format B). Both these frequencies fall within the normal FM broadcast band, and indeed the very simplest solution is to connect the aux "70 MHz" IF output (pre-filtering) to the external antenna socket of an FM radio, and tune to 88.5 or 96.5 MHz. In Fig. 37 an extra oscillator is used, switchable or tunable between 95 and 103 MHz, so as to produce a difference frequency of 6.5 MHz (say), in the center of the tunable subcarrier demod's range. The 85 - 100 MHz filter merely rejects the image frequency of this conversion - there are other ways to do it. The extra oscillator could be crystal-controlled, so removing a source of **drift**, but that is insignificant compared to the drift of the downconverter.

Consider: the FM SCPC signal is between 180 and 360 kHz in bandwidth, according to source. The FM TV is 18 MHz wide. A scale factor of 50 to 100. The downconverter is specified to have a frequency stability "good enough for TV". In the home terminal world that means full transponder TV, say 36 MHz. So the ratio is now 100 to 200. **The video signal can drift by perhaps 5 MHz** before any drift is noticed. But 250 kHz sees the audio completely off tune. This is a problem that **doesn't occur** with subcarrier sound, demodulated from baseband - it rides along on the video.



G.E.O. SATELLITES, 1982

BY FREQUENCY BAND AND ORBITAL STATION

(Not to scale)

© S J Birkill 1982

A suitable stability requirement for SCPC audio (wide-band FM) would be ± 25 kHz, for a home receiver, 200 times better than the video needs. A drift of 25 kHz in 4 GHz represents a stability of 1 part in 160,000, and is certainly not met by the average VTO! Immediately this points to the use of a **block first downconversion** with a crystal-controlled, or at least dielectrically-stabilized, local oscillator. In the professional world of INTELSAT **all** conversions are crystal-locked, and even then the transponder pilot is used to compensate for drift in SCPC systems. For a low cost system we must consider the possibilities for AFC (Automatic Frequency Control).

Most receivers apply video-derived AFC to the VTO, along with the tuning voltage. That holds the video IF **mean frequency** reasonably constant (provided the VTO doesn't go too far), and so also looks after a fair bit of the drift that will afflict our audio tuning. A good AFC system might hold the tuning steady to ± 1 MHz, but we must still cope with video mean level (APL) variations with change of picture content, and any "bounce" on scene changes introduced by the uplink modulator. **Clamped** AFC doesn't get around these problems - the tuning might follow the video black level faithfully, but if that swans up and down in frequency relative to the SCPC audio, it's no help at all. So realistically we have an AFC'd tuning stability of perhaps ± 2.5 MHz, within which the audio demod's own AFC must attempt to track the SCPC carrier. **There's a challenge for the designers.** The pilot is no help either - although it's bigger than the message carriers, it's not in the same league as the TV sound carrier. But if you end up leaving the delighted customer to chase the audio up and down the band, do him a favor and disable the video AFC. Then he'll only have to chase slowly, as when the sun shines on the down-converter, or when the wind blows.

All of the above assumes the 70 MHz spectrum is "right way up". The receiver manufacturer should know whether it is **erect** or **inverted**. If you have an **odd number** of "high side" downconversion oscillators then you'll have to think again - the SCPC sound carriers will come out at 43.5 and 51.5 MHz - not so convenient for the FM radio approach. If your sound carriers don't come up quite where you expect them, having tuned for best video, it could be that your video demod is not precisely **centered** on 70 MHz. It may be possible to adjust it, but you'll probably find it preferable to alter the SCPC conversion oscillator frequency (or re-tune the FM radio).

Tackling an operation like Saudi Arabia, where the SCPC audio is in another transponder, complicates things still further. Two receivers is one way, split at 4 GHz from the LNA output. Better, two second converters, split at first IF in a block-downconversion system. The first way you'll probably need to link both converters to the video AFC, in proportion as necessary, to hold the sound receiver somewhere near. The worst case would be a totally independent sound receiver whose (unused) video department was trying to lock onto whatever (non-video) signal was in the lower half of the "sound" transponder.

In the block downconversion system, the two second converter outputs can then feed the vision and sound IF inputs of the modified receiver, going in place of the IF splitter outputs in Fig. 37. Again, first oscillator stability is the key to stable performance, with AFC going some way

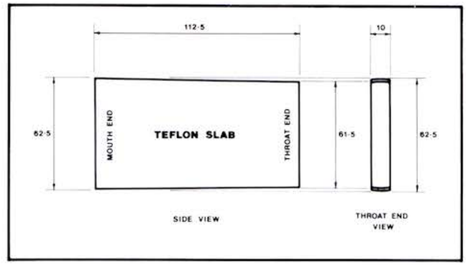


FIGURE 38. CIRCULAR POLARIZER IS CUT FROM TEFLON SHEET 10 mm or 3/8 INCH THICK. TAPER IS REQUIRED TO ENSURE A SNUG FIT IN THE CHAPARRAL HORN.

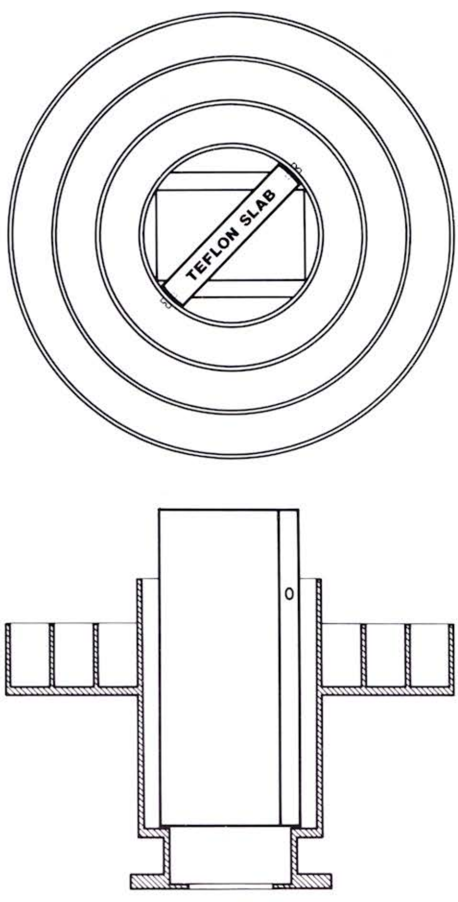


FIGURE 39. PLAN AND CROSS-SECTIONAL VIEWS OF CHAPARRAL SUPER FEED II, showing insertion and orientation of polarizer vane for right-hand circular. Two small self-tapping screws (no longer than 3 mm) hold the polarizer in place, as it will slacken in cold weather.

ANTENNA APERTURE (METERS)	LNA NOISE TEMPT (KELVIN)	THRESHOLD EIRP (dBW) at ELEVATION:			
		4 - 8°	9 - 14°	15 - 30°	over 30°
2.0	120	38.9	38.2	37.4	36.9
	100	38.4	37.7	36.9	36.4
2.4	120	37.2	36.6	35.8	35.3
	100	36.7	36.1	35.2	34.7
3.0	120	35.2	34.6	33.8	33.3
	100	34.7	34.0	33.2	32.7
	85	34.2	33.5	32.7	32.2
3.7	100	32.9	32.2	31.5	31.0
	85	32.5	31.8	30.9	30.4
	75	32.2	31.4	30.5	30.0
4.5	100	31.1	30.4	29.6	29.2
	85	30.6	29.9	29.1	28.6
	75	30.3	29.5	28.7	28.2
6.0	100	28.4	27.8	27.0	26.6
	85	27.9	27.3	26.5	26.1
	75	27.6	26.9	26.1	25.7
	65	27.2	26.5	25.7	25.3
7.5	85	25.9	25.2	24.5	24.1
	75	25.5	24.9	24.1	23.7
	65	25.1	24.5	23.7	23.3
	55	24.7	24.0	23.2	22.8
10.0	75	22.8	22.1	21.4	21.0
	65	22.5	21.7	21.0	20.6
	55	22.0	21.3	20.5	20.1

FOR A RANGE OF POPULAR ANTENNA SIZES AND LNA NOISE TEMPERATURES, THIS TABLE SHOWS MINIMUM EIRP REQUIRED AT 4 GHz FOR THRESHOLD WORKING WITH STANDARD DEMODULATOR IN FULL TRANSPONDER (25 MHz) BANDWIDTH, AT VARIOUS ELEVATION ANGLES TO THE SATELLITE.

TO THESE EIRP FIGURES: ADD REQUIRED MARGIN ABOVE THRESHOLD (0 to 3 dB)

and SUBTRACT 2.2 dB IF RECEIVING HALF-TRANSPONDER TV WITH A HALF-TRANSPONDER BANDWIDTH RECEIVER

and SUBTRACT 3.0 dB IF USING PLL or THRESHOLD EXTENSION

and SUBTRACT 1.5 dB IF YOU CAN TOLERATE MODERATE SPARKLIES OR IF RECEIVER HAS VIDEO IMPULSE CANCELLATION.

(TYPICAL VALUES OF ANTENNA ILLUMINATION EFFICIENCY AND NOISE TEMPERATURE HAVE BEEN ASSUMED) to help.

AVCOM of Virginia have a switchable half-transponder option available on one of their receivers, but I haven't had the opportunity to evaluate it. It can apparently be combined with a "tweakable" threshold extension feature.

British company **Satellite TV Antenna Systems Ltd.** are developing a fully INTELSAT-compatible receiver, to add to their range of equipment for the OTS/ECS, SYMPHONIE and GORIZONT transmissions. This company markets terminals of up to 7.5 meters in Europe, the Middle East and Africa.

CIRCULAR POLARIZATION - MODIFICATION OF A LINEAR FEED

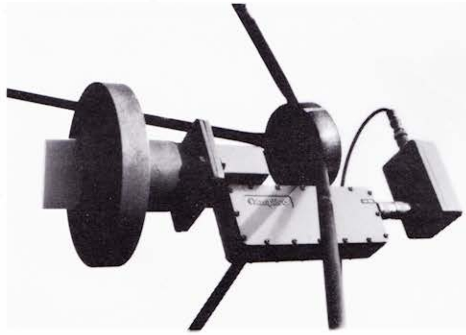
As a glance at Fig. 3 will show, whilst domestic systems have in general adopted plane (linear) polarizations, most of the international satellites employ **circular polarization**, either left- or right-hand.

There's nothing fundamentally difficult about CP, the electromagnetic field vectors being rotated by 90 degrees about the axis of propagation with each quarter-wavelength travelled. This rotation can be either clockwise or counter-clockwise, hence the two senses of CP. The advantage is that a precise angle does not have to be defined (and agreed between transmitter and receiver), merely a sense of rotation. And any influence which would change the plane of a linearly-polarized wave (such as Faraday rotation in the ionosphere, or change of satellite attitude, or misalignment of your feed rotation) has no effect on CP. For frequency re-use, the same order of isolation can be achieved between LHCP and RHCP as with horizontal and vertical orthogonality.

Try to receive circular polarized signals with a linear feed, and you'll find you can. In fact, you'll get both LH and RH simultaneously, whatever the angle of your feed probe. And you expected the INTELSAT (or whatever) signals to be weak anyway, so you might not realize you've lost 3 dB of signal. Because if you pick up CP signals with a linear feed (or vice versa) you collect only **half of the signal power** coming into your feed horn. The other half doesn't see your LNA probe and so reflects back out into space.

The polarizer shown here adapts the standard 4 GHz Chaparral "Super Feed" for circular polarization. It forms a "birefringent" structure within the circular waveguide of the horn, by making the guide behave as if it is wider in one direction than the other. This slows down the wave's propagation in one linear component direction, allowing the orthogonal direction to "catch up" by a quarter wavelength and come into phase, so depolarizing the CP. The resulting linearly polarized wave, its electric field vector aligned with the LNA probe, looks to the LNA like any other plane wave. Correct alignment occurs when the PTFE (**"Teflon"**) polarizer vane is at 45 degrees to the LNA probe. There are two ways of doing that, one giving response to RHCP (as shown in Fig. 39 for a single-reflector antenna), the opposite being for LHCP.

PTFE was used in the prototype as being readily available, not too expensive and (above all) low loss. Insertion loss can probably be improved by the choice of material of higher dielectric constant (relative permittivity).



That will enable the same polarizing effect to be obtained at a **lower volume** of inserted dielectric material, giving reduced losses. The proprietary microstrip substrates with dielectric constant around 10 should be worth investigating, though they are more costly than PTFE.

If remote selection of left- or right-hand is required, as with a motorized installation for INTELSAT and SYMPHONIE, the **Chaparral "Polarotor"** is recommended. This feed has a rotatable probe to select vertical or horizontal polarization which, with the polarizer inserted, will receive left-hand or right-hand circular. In fact, if the angle of the polarizer is set parallel to meridian horizontal or vertical (in a **modified polar mount** antenna) then the Polarotor will give access to **all four types of polarization** over 135° probe angle range. It is understood that Chaparral now have a version of the "Super Feed II" with a dielectric vane polarizer fitted, but they have not yet modified the Polarotor.

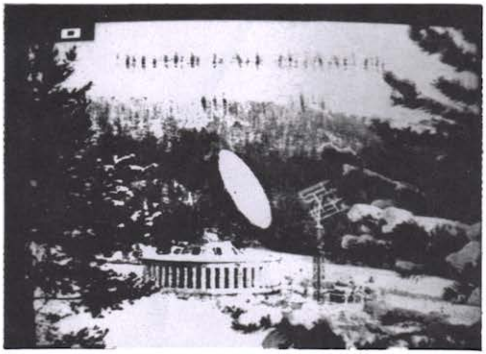
THE SOVIET COMMUNICATIONS SATELLITES

Russia was first to place a satellite into any kind of orbit, with SPUTNIK-1 in 1957. Not surprisingly it was the Soviet Union which established the world's first domestic communications satellite system, "ORBITA" (Orbit) in 1965, just three years after TELSTAR-1, with the launch of four MOLNIYA (Flash) satellites.

A primary requirement was distribution of Central Television from Moscow to remote communities across the wastes of Siberia, where no television had gone before. The difficulties were compounded by the geographical fact that the USSR spans **eleven time zones**. Prime time evening programming from Moscow would not find much of an audience at 5 a.m. on the Bering Sea coast.

Secondary communications needs included the facsimile transmission of newspaper pages, to permit the state newspaper **Pravda** to be printed and published simultaneously at various locations across the Soviet Union, and also the relay of domestic radio program services to regional studios and transmitters.

The Orbita system still operates in 1982, and there are no signs to suggest imminent obsolescence. Soviet TV is still working towards full time zone coverage, via satellite, of the I and II Programma national channels, and the domestic operation has been augmented by a number of



Russian weather slide for Siberia shows a 12-meter Orbita station. Dish is probably aligned on RADUGA at 85°E, and yagi stack on EKRAN at 99°E. This is evidence to suggest the Statsionar-3 RADUGA relays a version of the Moscow 2nd program.

geostationary birds, including a UHF DBS.

In addition, the Soviet bloc nations are now linked by INTERSPUTNIK, an organization analogous to INTELSAT, with Orbita-class earth stations (12 meters) installed in Afghanistan, Algeria, Bulgaria, Cuba, Czechoslovakia, East Germany, Hungary, Iraq, Laos, Mongolia, Nicaragua, Poland, Rumania, Syria and Vietnam, as well as the USSR.

THE MOLNIYA ORBIT

The orbit chosen for the Molniya spacecraft is second only to the Clarke orbit in communications potential, with the bonus of visibility of the north polar region. The **Baikonur** cosmodrome at **Tyuratam**, 46°N, is **less favorable than KSC** for equatorial launches, and the military launch site at Plesetsk (63°N) is worse. The Soviet Union did not achieve geostationary payload capability until 1974 with Kosmos 637. In 1965 an inclined orbit was the natural choice. The MOLNIYA orbit, period just under twelve hours, inclination 63 to 65 degrees, eccentrictiy 0.74 and argument of perigee close to 285 degrees, has what at first might seem remarkable properties. Firstly it repeats the same ground track, despite precession forces and the Earth's motion around the Sun, and secondly it appears to spend six hours of each revolution close to one of two quasi-stationary points in the northern sky.

This phenomenon is due to the Earth's rotation "catching up with" the satellite's eastward motion near the slow moving apogee point of the orbit, some 40,000 kilometers above the Earth's surface. In fact, the Earth "overtakes" the satellite and for a part of this loop it appears to climb back westwards, before sliding off south-east to perigee in the southern hemisphere.

The Earth's triaxiality limits the number of possible stabilized ground tracks of this type, and the Russians chose an ascending node in the region of 113°W (and 67°E), placing the apogees over 75°W and 105°E, with the orbit's northerly apex at 63°N.

Fig. 40 shows the MOLNIYA ground track (path of the

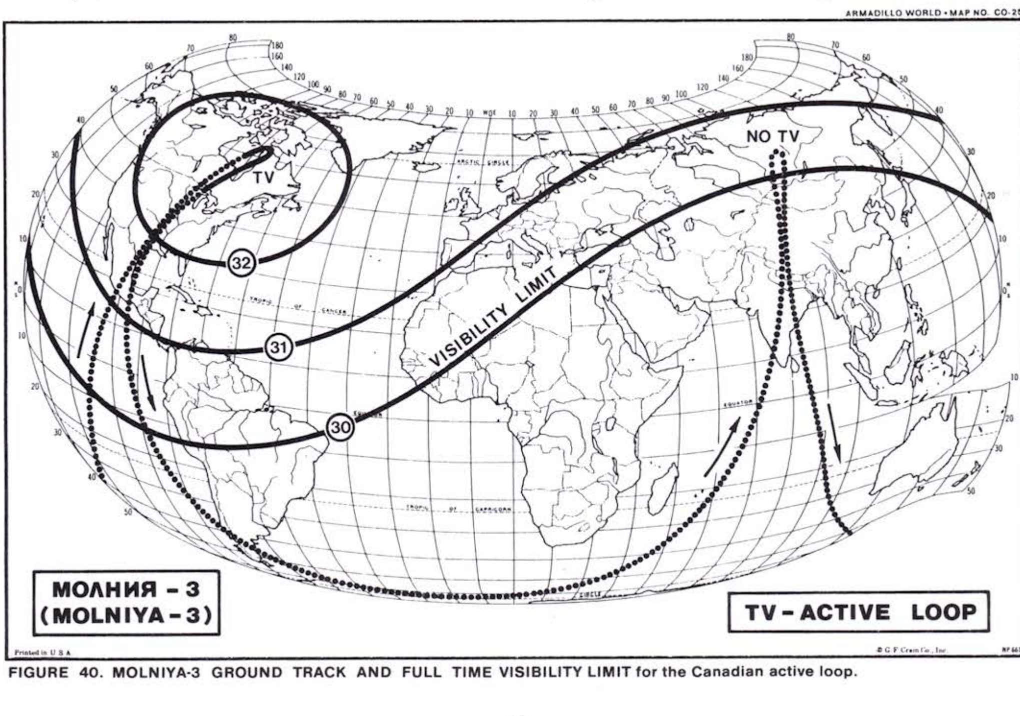


FIGURE 40. MOLNIYA-3 GROUND TRACK AND FULL TIME VISIBILITY LIMIT for the Canadian active loop.

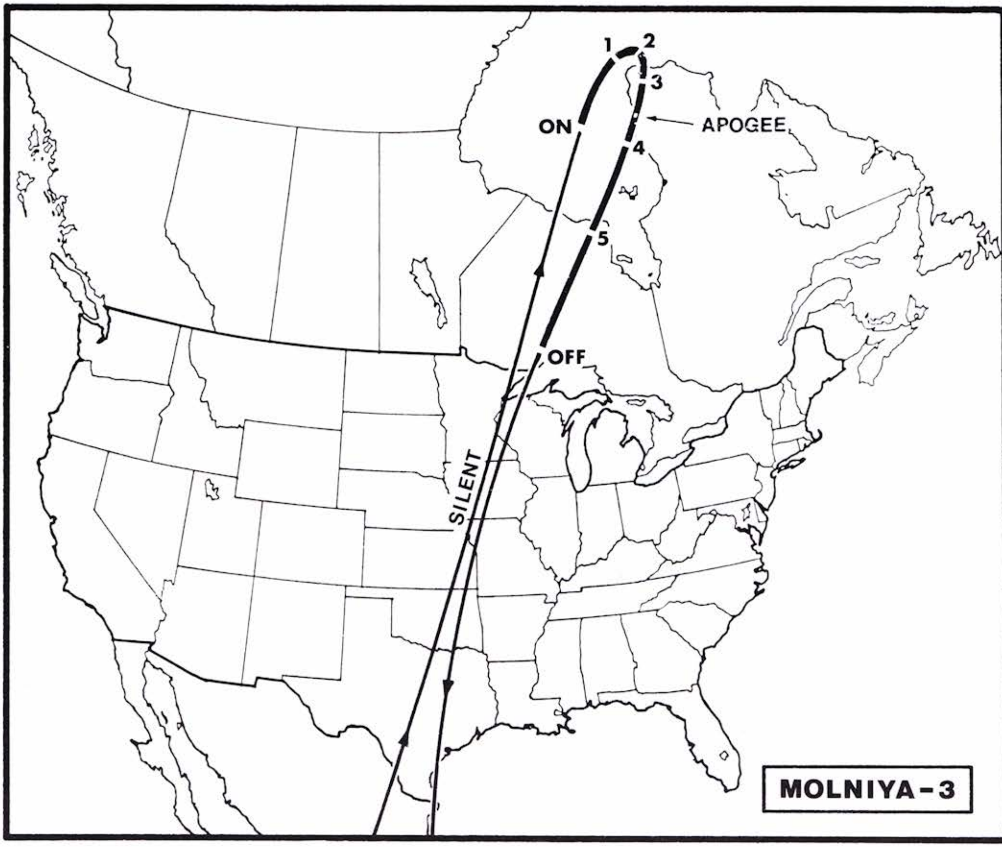


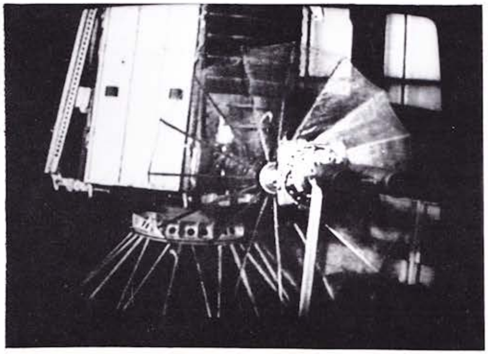
FIGURE 41. MOLNIYA is directly overhead at Hudson's Bay and Ontario province during the six-hour period each bird relays Moscow TV.

sub-satellite point) as the dotted line. The two narrow northern hemisphere loops are readily identified. The precise shape of the loop depends upon **argument of perigee** (the position within the elliptical orbit of its closest approach to Earth) - at values below 283° it crosses over on itself and aligns more closely north/south. Above 283° the loop is wider and tilted further to the east. A typical MOLNIYA shape is shown - there is a total spread of some five degrees in this parameter.

It has been widely assumed that the loop over the USSR was used for TV relay, offering maximum visibility period, but our observations in 1978 proved that it is now the **western apogee point, over Canada**, which downlinks Moscow TV back over the pole into the Soviet Union (it is also in view from Cuba). Fig. 41 shows a "close up" of the ground track in the vicinity of this apogee.

MOLNIYA-1

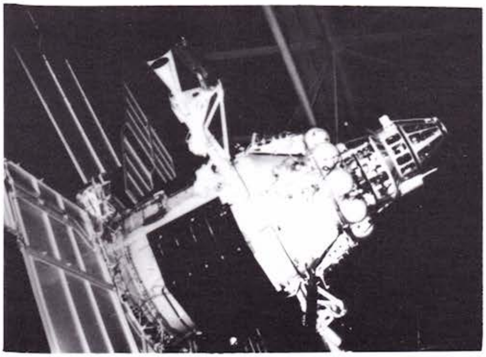
The first MOLNIYA satellites operated in the UHF band, with a downlink frequency range of 970 to 1000 MHz



A Russian Luly? This shot of a MOLNIYA-1 with antenna deployed and solar panels stowed, comes from a space film shown on Soviet TV.

approximately, according to our observations. Uplink is believed to be around 800 MHz, and downlink EIRP some 30 dBW, right-hand circular, from one of a pair of 1-meter deployable paraboloids extending from the 3-axis stabilized spacecraft body. The Orbita-1 terminals were equipped with 12-meter focal plane antennas.

Initially the MOLNIYAs were flown as a group of **three** with orbital planes spaced 120° apart, each spacecraft carrying communications traffic for **eight hours** before handing over to the next, so giving full 24-hour coverage. Later flights fell into a **four**-satellite pattern with 90° spacing, the birds following one another at **six hour** intervals along the same ground track.

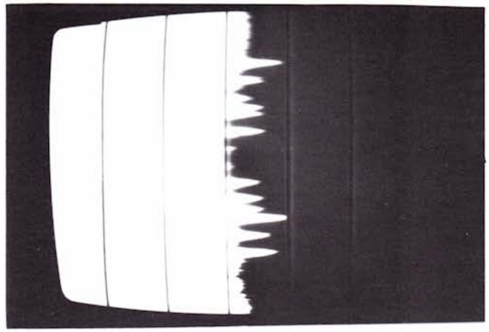


MOLNIYA-2, Paris 1973.
4 and 6 GHz global horns are visible in this photo, by Geoff Perry..

MOLNIYA-2 and MOLNIYA-3 SATELLITES

In 1971 the first MOLNIYA-2 was launched, with C-Band transponders. Downlink band was 3400-3900 MHz, and the TV service was dual-fed on the two systems while the Orbita terminals were updated to the Orbita-2 specification. MOLNIYA-3 launches began in 1974, eventually replacing MOLNIYA-2 in the Orbita-2 system (the 17th and final MOLNIYA-2 launched in 1977). MOLNIYA-3 satellites conform to the current Soviet C-Band plan (Fig.3). Both MOLNIYA-1 and MOLNIYA-3 launches continue, with two interleaved 4-satellite groups serviced by MOLNIYA-1 birds (one of these may have a purely miltary role) and one such group maintained of the MOLNIYA-3 class, which performs the TV relay function. That's twelve operational MOLNIYA satellites to be watched by the control stations at Vladimir and Shchelkovo, near Moscow. To date there have been 53 MOLNIYA-1 and 19 MOLNIYA-3 launches (excluding failures).

The MOLNIYA-3 birds are equipped with three similar transponders on 100 MHz centers (Fig. 3). Usable bandwidth is some 34 MHz. TV relay is in channel 10 [9], currently on the Canadian loop with the **"Orbita-I"** channel, a version of **I Programma** timed for the extreme far east of the Soviet Union, 8 hours ahead of Moscow time. So it's not long past midnight when the Moscow announcer says "good morning" to Orbita-I viewers. The other transponders are used for FM/FDM telephony,



MOLNIYA channel 8 over Canada. The Hot Line is in there somewhere.

teleprinter and data traffic. Channel 8 [4] provides a part of the **Direct Communications Link** ("hotline") system between Moscow and the purpose-built MOLNIYA terminal at Ft. Detrick, Maryland.

Downlink is RHCP from a "global" coverage horn antenna, and estimated EIRP contours are shown in Fig. 40. There is some PFD variation as satellite altitude changes over the 6-hour "active loop", despite closed-loop EIRP control The visibility limit on this map is the worst case over the full 6-hour active period - the satellites are visible somewhat farther south when close to apogee.

I've published previously a "MOLNIYA-Finder" map for North America, where the satellites go directly overhead. Here (Fig. 42) is the global version. This shows azimuth and elevation contours to the center of the active loop, and should put your antenna within ten degrees of a MOLNIYA, at any time of day or night. A little scanning should reveal the instantaneous location - the signal is present normally 24 hours per day, with a test pattern outside program hours. Video is 625 lines with SECAM color, and the program sound is transmitted by audio-frequency modulation of the width of one of two white-level pulses in a modified horizontal blanking interval. This pulse-width modulation constitutes a rudimentary form of "sound-in-syncs". A 7.5 MHz audio subcarrier carries an unrelated radio program feed.

TRANSFER OF SERVICE AT MOLNIYA "HAND-OVER"

Referring again to Fig. 41, the MOLNIYA transponders are silent as each bird comes in from the west, over Texas 110 minutes before switch-on, crossing the Canadian border just after passing over Duluth at 90 minutes to go. As the incoming satellite reaches 33,000 km over Hudson's Bay, ten seconds before hand-over, its transponders are powered and noise can be seen in the downlink band. At this point it is possible to recognize specific MOLNIYAs by their individual fingerprint, the shape of the noise spectrum, never completely flat, as seen on a spectrum analyser. Then, as the appointed time arrives the Moscow uplink slews rapidly (typically 1

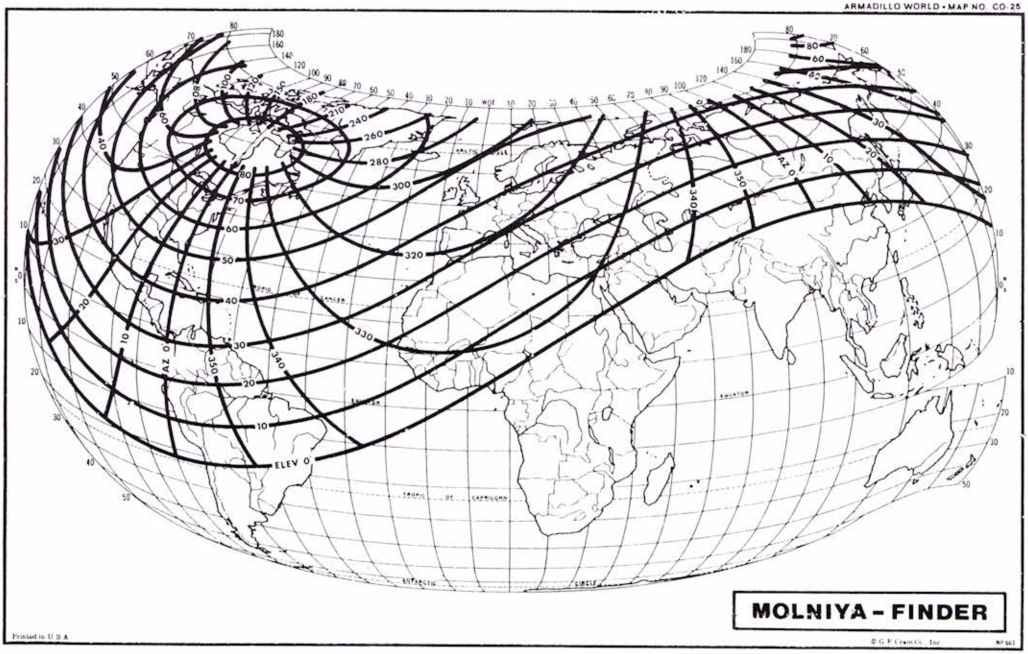


FIGURE 42. LOOK ANGLES TO THE CENTER OF THE ACTIVE LOOP.

second) to the incoming bird and the outgoing MOLNIYA is immediately turned off, to pass southwards over Lake Superior and the USA, skirt the Gulf of Mexico and increase speed towards its 600 km perigee over the South Atlantic.

Over the next six hours the active bird climbs steadily to its apogee, 40,000 kilometers above the north-east corner of Hudson's Bay, then back down towards the Earth, gathering speed towards the end of its active loop when it too is replaced by the next MOLNIYA coming up from the south. The TV channel is not dual-fed at handover, so the receiving Orbita terminals must all slew to the new bird at the right instant. It may be done by the clock, or there may be a cue somewhere - I haven't found one. Interestingly one set of the MOLNIYA-1 birds downlinking at UHF **does** feed via two satellites simultaneously at handover. Their service must be more important than TV.

The MOLNIYA satellites are of little interest to those of us within range of the Soviet geostationary systems, though they do offer the USA's only access to Russian TV, away from the eastern states where the Atlantic GORIZONT can be seen. The need for tracking makes their acquisition and use more troublesome, as does the audio multiplexing format. A combination of computer prediction and step-tracking on an el/az or (preferably) X/Y mount would seem the best way to go - an absolute maximum tracking rate of 0.25 degrees per minute is required (away from the zenith singularity of an el/az mount), the MOLNIYA orbit can be accurately modelled on microcomputer, and orbital predictions are available from NASA (GSFC).

When tracking manually, be aware that the orbital period of 717.75 minutes means that the ground track repeat (and hence the handover time) is about 4.5 minutes earlier each day. This is not just the 3 min 56 sec difference between the sidereal day and the mean solar day, but includes a factor for orbital precession rate as well. Note also that transfer of one 6-hour period to a newly-stabilized MOLNIYA may mean a "jump" in some of the handover times due to the spread in orbital parameters from bird to bird. Bob Cooper has described his experiences in manual MOLNIYA tracking in **Coop's Satellite Operations Manual** (from STTI).

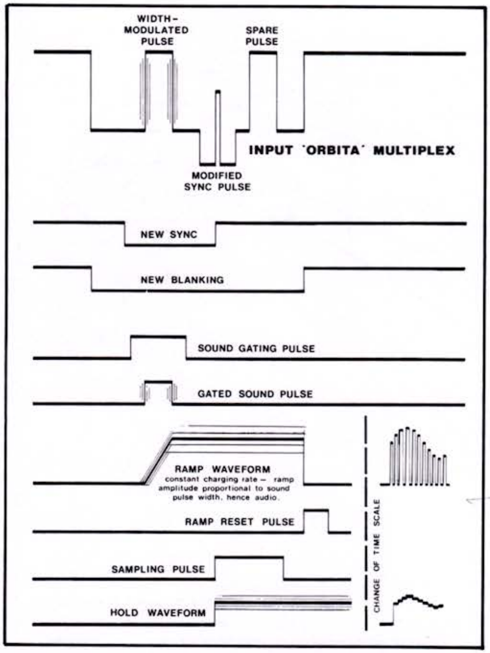
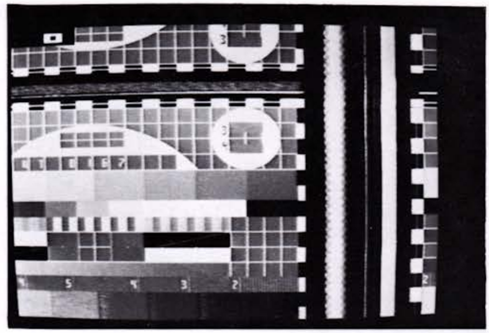


FIGURE 43. WAVEFORMS IN A MOLNIYA/ORBITA SOUND-IN-VISION DECODER.



MOLNIYA TV, picture phased to show the two sound pulses (the first is tone modulated) as well as the SECAM field ident 'bottles'.

DECODING THE ORBITA MULTIPLEX

Back in the days of MOLNIYA-1 TV, before the world had settled on FM subcarrier as the preferred method of satellite TV sound transmission, the Soviet Union's TV transmission engineers devised a method of audio **multiplexing** within the video band, a method they still use today on certain satellite circuits. The horizontal blanking period (line suppression interval) is modified at the uplink to incorporate two pulses at white level, and a narrowed, displaced sync pulse (Fig. 43). Pulse amplitude remains constant, but the pulses can have their

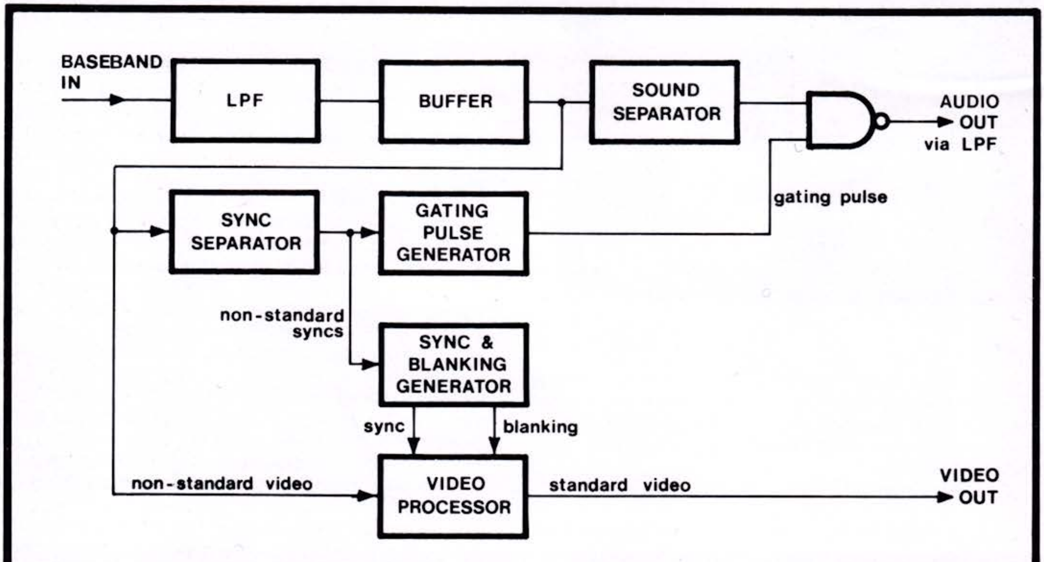


FIGURE 44. BLOCK SCHEMATIC OF SIMPLE ORBITA DECODER.

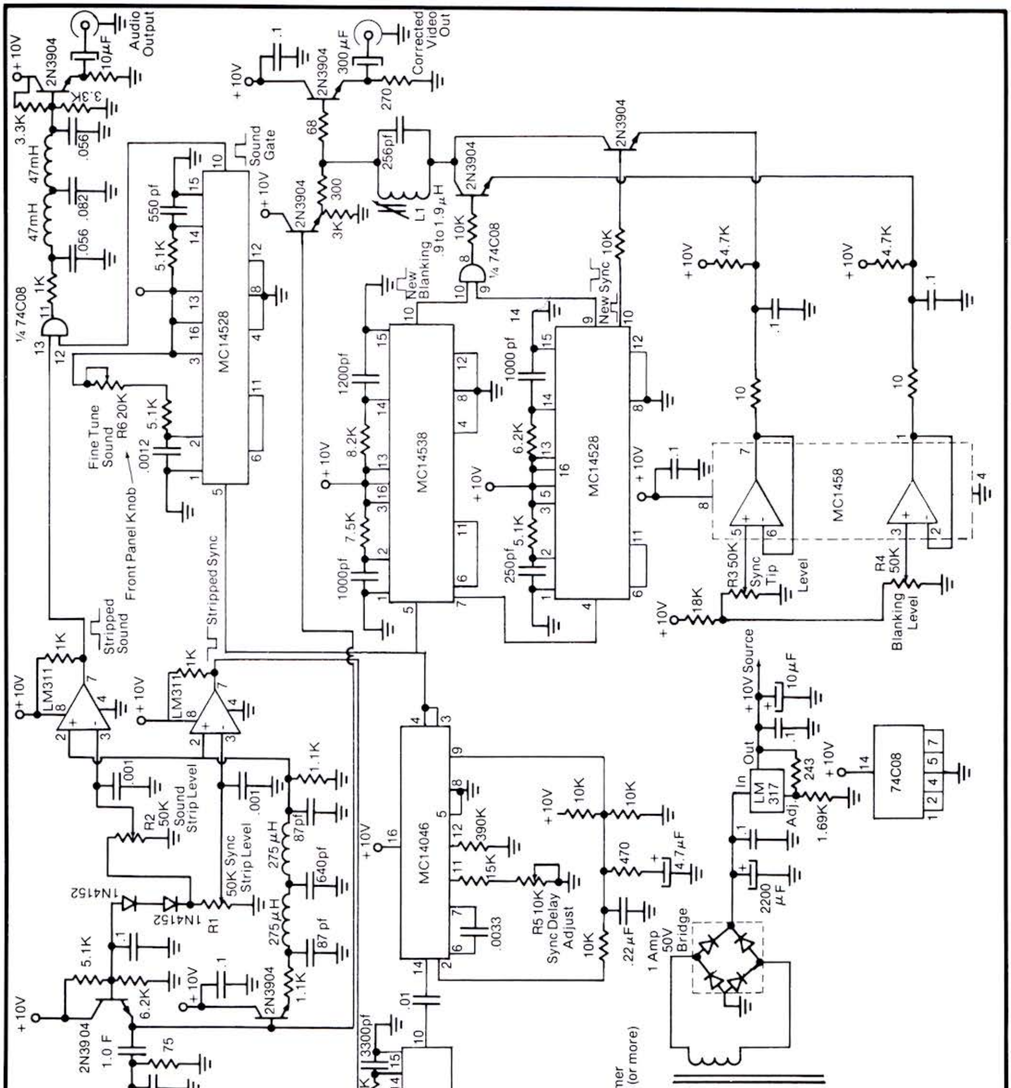


FIGURE 45. CIRCUIT SCHEMATIC OF DECODER DESIGNED BY LYNN HURD AND TOM HILL.

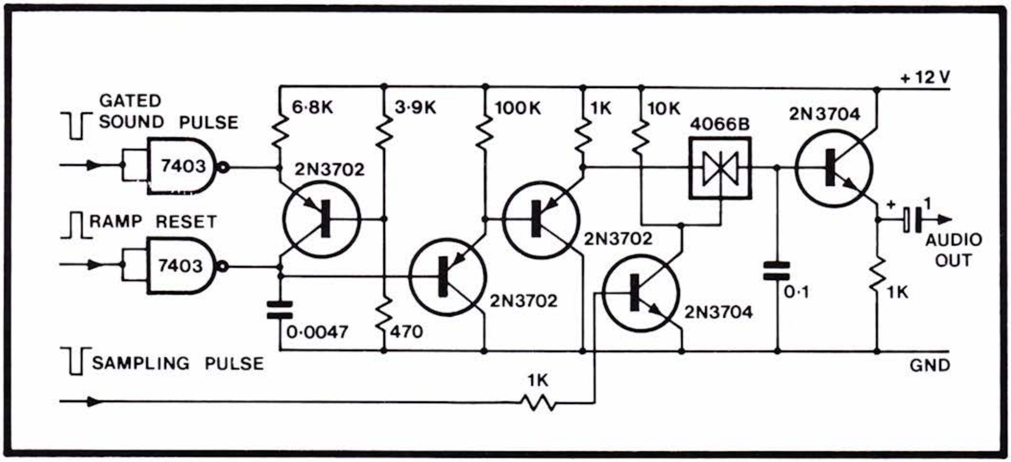


FIGURE 46. SUGGESTED Ramp generator and sample/hold circuit for improved decoder.

widths modulated, above and below the mean 1.5 microseconds, by an audio signal. This gives them the appearance of the old type optical film soundtrack (see photo). Each pulse can carry an independent sound channel, though most of the time only one is modulated. As each pulse recurs at a rate of 15.625 kHz, maximum audio frequency is limited to around 7.5 kHz, though this appears to be adequate for the Russian TV sets.

To decode this multiplexed signal two operations are required, the pulse-width demodulation of the audio from the selected pulse, and the restoration of the video waveform to normal (the non-standard waveform will cause horizontal displacement and flyback bright-up on a standard TV.) So new horizontal sync and blanking pulses have to be generated (Fig. 43), timed to the modified sync. Also an appropriately-timed gating pulse, wide enough to pass the sound pulse without clipping on full modulation but without either allowing any video through. The gated sound pulse will then be seen to have a component at audio frequency, requiring low-pass filtering (to remove 15.625 kHz whistle) and amplification. Fig. 44 shows a block schematic for such a decoder.

Following a "paper design" of mine for this decoder, Lynn Hurd and Tom Hill of Beaverton, Oregon, developed an improved version using a comparator-type sync separator which is reported to give excellent results (Fig. 45). They also point out the advisability of disabling the receiver's clamp or DC restorer, which could easily damage the narrow sync pulse of the Orbita system.

A further refinement would take the form of a **sample and hold** circuit to derive audio directly from the separated sound pulse. A current source charges a capacitor to generate a **linear ramp**, but only for the duration of the sound pulse. The amplitude reached by the ramp is a linear function of pulse width, and the capacitor holds this potential after the current source is turned off. A sampling pulse is timed so as to read the potential into a hold capacitor, updating its previous charge once per line. The ramp is then discharged ready for the next sound pulse, Fig. 43. The result is a **stepwise replica** of the modulating audio which is readily filtered to remove the line frequency component, delivering better signal/noise ratio and frequency reponse than the basic **averaging** demodulator. A suggested circuit is shown in Fig. 46.

This complication exists only on the MOLNIYA and certain RADUGA feeds - other Soviet systems employ the standard 7.5 and 7.0 MHz subcarriers, or 6.5 MHz in the case of EKRAN.

STATSIONAR

MOLNIYA-1-S was one of a kind. In July 1974 it became the first (and last) MOLNIYA to attain geostationary orbit. The Soviet Union had announced its plans for a global Clarke orbit network, designating the various orbital locations with "Statsionar" (stationary) numbers. They had tested orbit insertion capability with Kosmos-637 and they now tried a MOLNIYA up there.

RADUGA

The first **operational** geostationary comsats were of the RADUGA (Rainbow) class to the Statsionar 1, 2 and 3 slots (80°E, 35°E and 85°E). Subsequently, just the 35°E and 85°E locations have been maintained with this type of satellite, RADUGA-10 being the most recent launch in October 1981. RADUGA may be based on the MOLNIYA spacecraft but we have no confirmation. It appears to carry six transponders, not quite fitting the standard Statsionar 50 MHz spacing, downlinking between 3450 and 3900 MHz, probably with global and/or "northern hemispheric" beams. I have access only to the RADUGA at 35°E (Statsionar-2), the source of my first Russian satellite TV in 1977, and can confirm that its only TV transponder is Soviet channel 10 [9] (as MOLNIYA-3). Signal level is consistent with the hemispheric footprint pattern of Fig. 47, and the TV service presently carried is

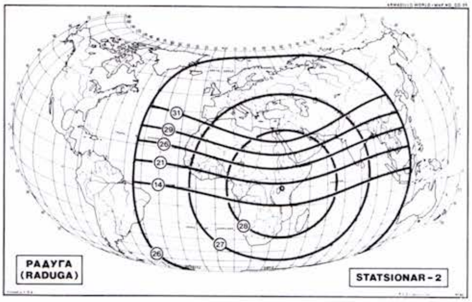


FIGURE 47.

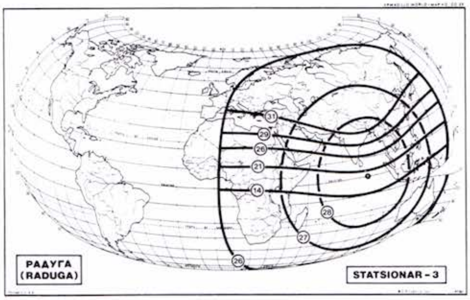


FIGURE 48.

The Statsionar-2 RADUGA (35° E) provides a mid-eastern feed of the 2nd program from Moscow.

called "**II Programma Dubl'-IV**", being a version of the Moscow second channel timed 2½ hours ahead of Moscow, suitable for Kazakhstan and the regions immediately beyond the Urals. Program sound is via the video-multiplexed analogue pulse-width modulation "sound-in-syncs" system of the Orbita network, and a 7.5 MHz audio subcarrier carries radio programming.

The other transponders contain a variety of FM/FDM and FM/SCPC message and data traffic, plus PSK data. Why, you might ask, do the Soviets divide their TV feeds among so many satellites when there is spare capacity apparent which could for instance put 1st and 2nd channels on the same bird, avoiding the need for dual antenna systems at the Orbita stations? I don't know.

As for the other RADUGA slot, Statsionar-3 at 85°W (Fig.48), I have no information on TV feeds. I would expect a far eastern feed of II Programma, timed the same as Orbita-I. Most likely on channel 10 [9], northern hemisphere. But I have no reports so this is only conjecture.

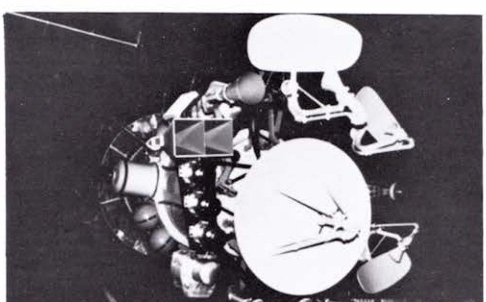
GORIZONT

GORIZONT-1 (Horizon) was launched in December 1978 to Statsionar-5 at 53°E. Except geostationary orbit insertion seems to have fouled up, leaving the bird in a rather eccentric inclined (11°) geosynchronous orbit. Nevertheless it seems to have operated as the primary Statsionar-5 bird until GORIZONT-3 came along one year later and achieved the correct orbit. GORIZONT-1 in fact remains stabilized over the Indian Ocean, apparently in a reserve role.

Meanwhile GORIZONT-2 established itelf in the Statsionar-4 slot at 14°W, a prime Atlantic location with a view of Cuba and the US eastern seaboard, as well as all of South America (Fig.49).

Now the GORIZONT was a much more sophisticated spacecraft. It sported six C-Band transponders downlinking between 3650 and 3950 MHz (Fig.3) with comprehensive beam switching, including access to a large steerable paraboloid similar to those of INTELSAT IV, generating a beam center EIRP of 46 dBW! The 3-axis stabilized bird also carried (it still does) an X-Band military communications payload, operating more or less independently of the C-Band loading.

When GORIZONT-2 struck up with 5 channels of TV and one of message traffic in August 1979 I couldn't believe the signal levels from my 2.4-meter dish. For the first few months the Russian engineers couldn't resist playing with their new toy. Beams were switched, a multiplicity of international feeds came and went with no apparent pattern, 7.0 and 7.5 MHz subcarriers sprouted on each video signal, first and second channels alternated on different transponders. **Every channel** was powered **24 hours per day**, with test card or pulse and bar if there was no program to occupy it. Eventually



A rare shot of a GORIZONT, taken by Dave Hawkins at the Paris Air Show, 1979.

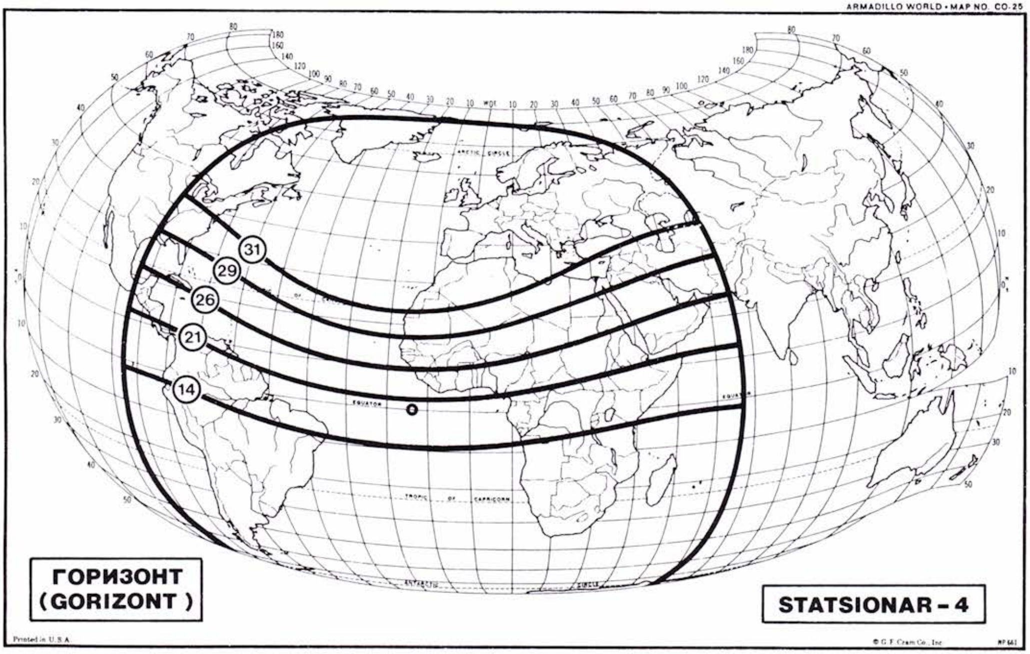
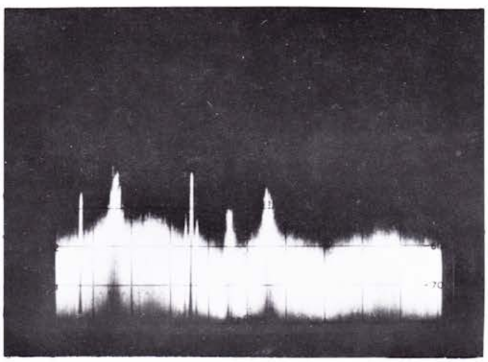


FIGURE 49.



During the 1980 Moscow Olympics the Atlantic Gorizont operated six transponders full time, five of them with television. Channel 8 (third from left) is occupied by low level SCPC carriers. Channel 6 (at left) was at this time on global beam.

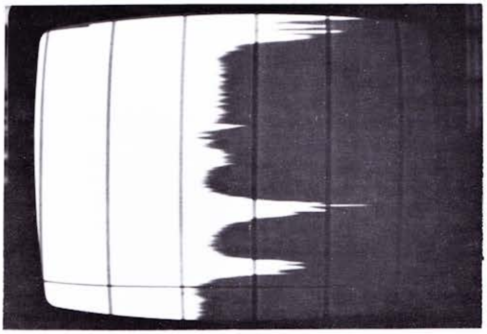
operations settled down to regular transmission of the Moscow 1st channel in tpdr 10[9] with various occasional feeds in the other transponders.

By early 1980 GORIZONT-2 was down to single TV channel operational (ch. 10[9]) apparently for Intersputnik program exchange. Feeds from all parts of Europe popped up on the channel, and there was no full-time Soviet TV service. So it remained until the end of June 1980 when the new GORIZONT-4 joined GORIZONT-2 in the Statsionar-4 slot. Right through the Moscow summer Olympic Games of that year all channels were active with 5 different TV feeds, multilaterals and unilaterals in all languages, disseminating the Games to the world. As many as four audio subcarriers were present on some channels, for commentary circuits.

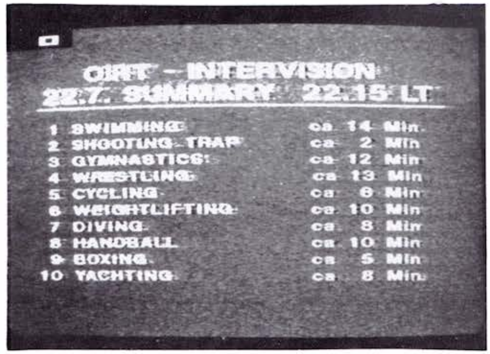
After the Games things looked a little more sober, and channel 6[-1] went into a new mode which had previously been seen testing on GORIZONT-2. EIRP was back up to the 46 dBW level (43 dBW here), a wide (5 MHz) slow (2 Hz) energy dispersal waveform was applied, the subcarrier audio was found to have its dynamic range compressed, and the Moscow **I Programma** was carried full time. This was the inauguration of the MOSKVA system in the Atlantic region. At the same time, transponder use was down to just three, with tpdr 10[9]either taking Intersputnik feeds or paralleling tpdr 6[-1] (but in standard format). Tpdr 8 [4] as always remained reserved for message traffic.

Another surge of activity on all transponders occurred around the beginning of 1981 with lots of dual feeding and remote sports, and relays off INTELSAT, only to settle back once again, this time with three TV transponders. Tpdr 6[-1]took **I Programma** in MOSKVA format, 9 [6] was spare for unilaterals, mostly being seen with 0167 electronic test card, occasionally taking **II Programma** or an Orbita feed, and 10 [9] as the Intersputnik channel with international exchange feeds, INTELSAT relays and prime time parallel feeds of I Programma for Intersputnik use.

This is the pattern of utilization continuing today, with no sign of reactivation of transponders 7[1] or 11 [11]. The only changes recently have been the relocation of one of



Today four transponders operate, including three with television.



The Olympics, summer and winter, featured heavily on the Atlantic GORIZONT during 1980.

the two Statsionar-4 GORIZONTs to Statsionar-6 (90°E) and the apparent revitalization in March 1982 of the ch. 6 [1] transponder which had over the course of the previous 6 months declined in power by almost 8 dB, at least to the UK, relative to its original EIRP level.

Over the Indian Ocean, things have not changed quite so frantically. All six channels have remained active on the Statsionar-5 GORIZONT (53°E), though only two with TV, and both of these full time feeds. Again ch. 6 [-1] is MOSKVA system relay of the channel "**Orbita-III Vostok**", a 5-hour advanced version of Moscow I for the people of Central Siberia, while channel 10 [9] is the thing now known as "**II Programma Dubl'-III**", being (economy at last) the second channel feed for the same region. GORIZONT-5 joined GORIZONT-3 at this location earlier in 1982.

MOSKVA SYSTEM TRANSPONDER

The standard Orbita station is equipped with a 12-meter antenna, receives TV programming from a MOLNIYA or a geostationary satellite, and feeds it to a standard terrestrial rebroadcast TV transmitter or via cable to a local community. The 29 to 32 dBW peak EIRPs of early systems demanded this class of terminal. With the advent of the GORIZONT satellites the Soviet planners had the option of a **high power** beam capable of operating a **semi-DBS** service to small terminals. The MOSKVA stations are 2.5-meter TVROs designed for unattended operation, delivering TV programs to terrestrial broadcasting transmitters or via cable, direct to local communities.

A 90°K uncooled parametric LNA is supplied, and the antenna is equipped with a simple step-track system, in case the satellite orbit stabilization should not reach specification. **Full-transponder video** format is used, with a special **wide-deviation energy dispersal** waveform to reduce interference to terrestrial microwave systems. Video signal to noise ratio is 54 dB minimum, with a 6 dB margin against threshold inside the 43 dBW contour. Two audio subcarriers are transmitted, with TV sound at 7.0 MHz and radio program at 7.5 MHz. **Pilot-tone controlled companding** is employed to achieve 57 dB signal to noise ratio in these channels.

The MOSKVA transmissions are downlinked exclusively from GORIZONT satellites in Soviet channel 6 (my numbering), center frequency 3675 MHz. A large dish antenna on the satellite is fed by a 15 watt TWTA (some sources say 40W) and generates a spot beam of 46 dBW EIRP at center. Figs. 50, 51 and 52 are my estimates of **possible** footprint patterns for this beam.

MOSKVA transmits Moscow's 1st program on the high power GORIZONT spot beam. Other feeds are often seen on the zone beam transponders.

MOSKVA stations are being installed in large numbers in the regions already covered. Russian military bases in East European Warsaw Pact countries are believed to be equipped with these TVROs.

During 1981, entrepreneurs in western Europe became aware of the MOSKVA downlinks and their commercial potential. US home TVRO equipment was imported and teamed with ex-PTT 2-meter dishes to form inexpensive TVRO systems. Those early traders had little regard for de-emphasis, dispersal or audio expansion, and some of the systems gave results of dubious quality, while requiring unnecessarily large antennas. That phase now seems to be past, and suppliers are realizing that **modification and realignment are necessary** if American gear is to be used - the next step is for the US manufacturers to get wise.

Soviet TV is now a commonplace sight at trade shows in Europe, and already it is carried, with official approval, on Dutch Cable TV systems. In the UK a well-engineered system will use an antenna of 2 meters or larger. Further east into Europe the footprint is stronger and antennas as small as 1 meter will deliver good results. It seems the Russians will accept end-of-life degradations of as much as 6 dB in EIRP, so such marginally-engineered systems are not recommended.

Program listings for all four Moscow TV channels (only the first two are on satellite) are published each day in the state newspapers Pravda and Izvestia. The Sunday issue gives program details for the week ahead.

MOSKVA SYSTEM: REMOVING THE DISPERSAL

TV transmissions on the Soviet birds do not carry the half field frequency triangular waveform so familiar on other systems providing energy dispersal - reducing the power flux density per unit bandwidth arriving at the Earth's surface, to minimize interference with terrestrial microwave links.

But the high PFD of THE MOSKVA system downlinks on tpdr 6 [-1] of the GORIZONT satellites means a strong potential for interference. So the Russians put the father and mother of all dispersals onto that carrier. Frequency of the triangular waveform is between 2 Hz and 2.5 Hz, much slower than normal,and deviation is a massive 6 to 8 MHz peak to peak. This adds to the standard 13 MHz peak video deviation, plus audio subcarriers, and goes a long way towards filling the 40 MHz nominal bandwidth of the GORIZONT transponders.

Now the Russians use a receiver bandwidth of 34 MHz, and we would probably like to see it in 30 or even 25 MHz, so we must all do something about that dispersal. Even if our clamps could cope with it, the video would **truncate** in our IF bandwidth on dispersal peaks, giving **pulses of sparklies**.

The solution is to apply **frequency feedback** of the dispersal, so effectively reducing its deviation to a value the DC restorer can handle satisfactorily. The easiest way to achieve this is to modify the receiver's existing AFC circuitry. Normally the AFC line is decoupled with large capacitors, leaving it the status of slowly-varying DC. If we were to remove **all** effective low-pass filtering then the entire DC-coupled baseband would be fed back to the VTO, forming itself a phase-lock demodulator and reducing IF deviation to near zero. The ideal is to roll off the feedback response enough to clobber the dispersal, but ensure the low frequency video components are not affected, causing field tilt.

Fig. 53 shows a low-pass active filter which will go some way towards restricting frequency feedback to dispersal components. In fact with this simple approach

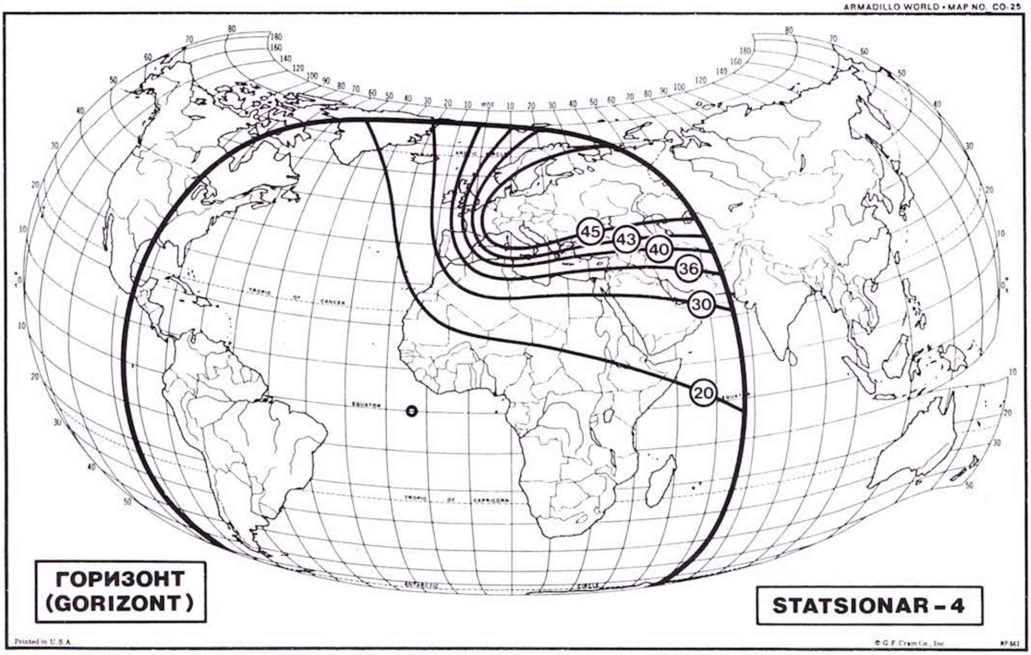


FIGURE 50.

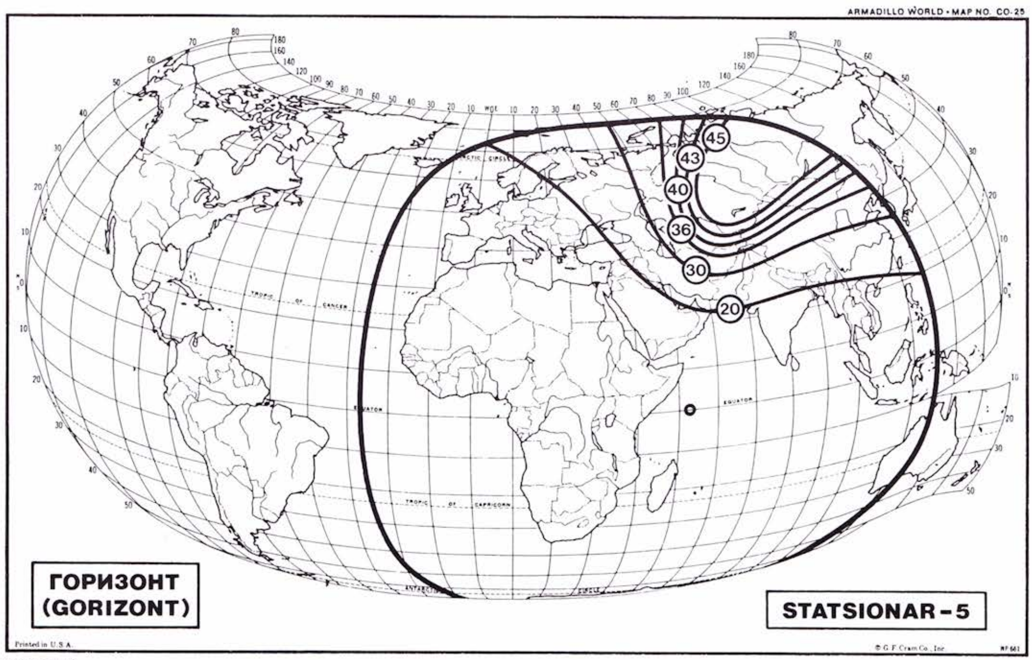


FIGURE 51.

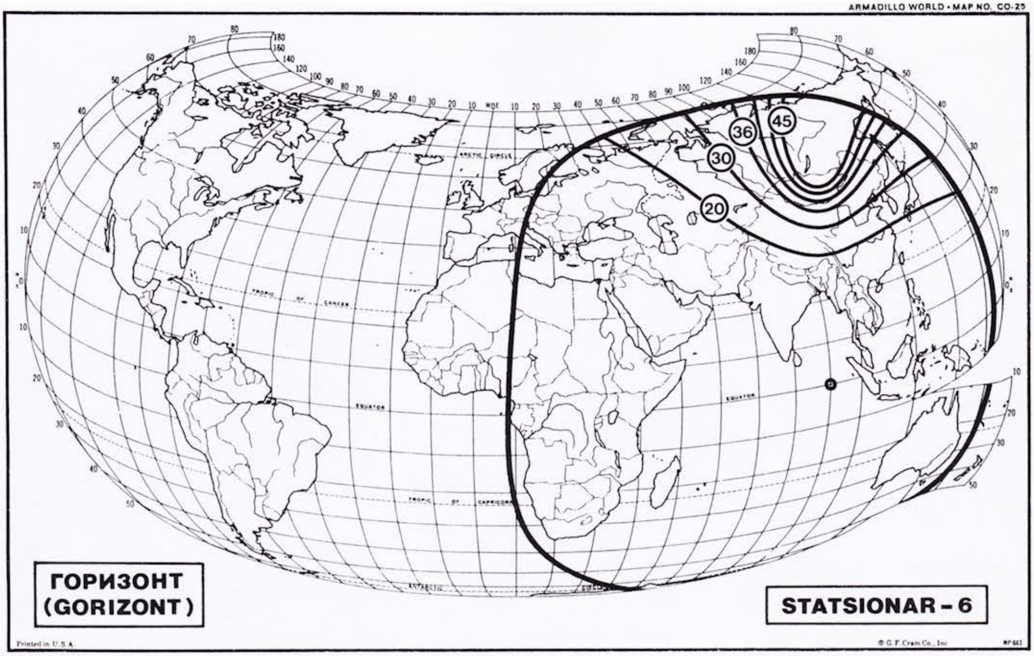


FIGURE 52.

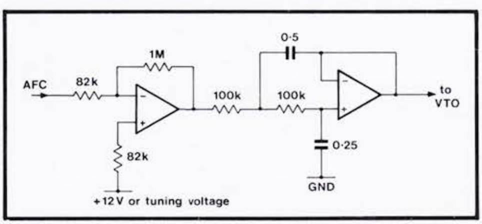


FIGURE 53. An op-amp active filter will tailor AFC response to cancel Soviet MOSKVA dispersal without distorting video.

the AFC waveform is a sine wave approximation to the dispersal, with some phase lag, but it takes the worst of it away and gives the clamp/DCR something left to think about at the turning points. Care should be taken to remove any other CR time constants, or phase shift around the loop can exceed 90° with potential instability. Op-amps are 741 or equivalent multiple package. Supplies are +24V, +12V and ground, permitting VTO tuning voltage to be summed with AFC in the first stage.

COPING WITH COMPANDING

The two sound channels on the GORIZONT transponder dedicated to MOSKVA (though not on the other transponders) achieve high signal to noise ratios by a process known as **companding**. At the uplink the audio has its dynamic range compressed by a non-linear process which brings quiet audio passages up to the same deviation as loud ones. The output level sits on "O" VU (PPM 6 if you prefer) when there's anything there at all. So unlike a linear compression process, the compressed audio doesn't itself reveal the instantaneous degree of compression. To convey this information and enable natural dynamics to be restored, a high frequency (11 kHz) pilot tone is added to the transmitted signal. This is amplitude modulated at syllabic rate by the compressor, and controls complementary expanders at the receive terminals. Expansion reduces the level of circuit noise along with the lower level audio passages, so increasing the SNR.

To achieve this the pilot and audio signals need to be separated. Soviet TV doesn't transmit audio frequencies above 10 kHz, so it is a straightforward process to filter the audio band (say 40 Hz - 10 kHz) from the 11 kHz pilot tone. Quality of the recovered audio depends upon the effectiveness of this filtering, in terms of (a) spurious operation of expander by high-frequency components in the audio (blasting on sibilants, or 'essing'), and (b) inadequate rejection of pilot tone, resulting in its audibility as a pulsating whistle. Soviet specification for the sound circuit is a 57 dB weighted audio SNR at link output.

The pilot tone is then amplified, detected and used to control the gain of a **voltage-controlled amplifier** which performs the expansion operation (Fig.54). An admittedly tacky realization of this circuit is shown in Fig.

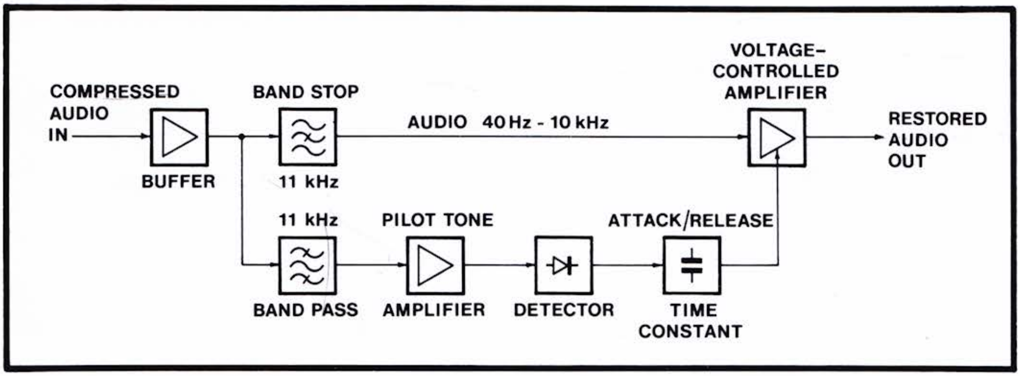


FIGURE 54. BLOCK SCHEMATIC OF MOSKVA SYSTEM EXPANDER.

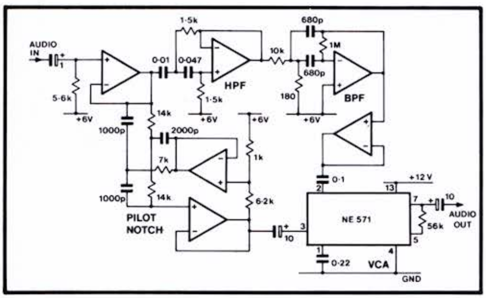


FIGURE 55. SUGGESTED BASIC EXPANDER CIRCUIT.

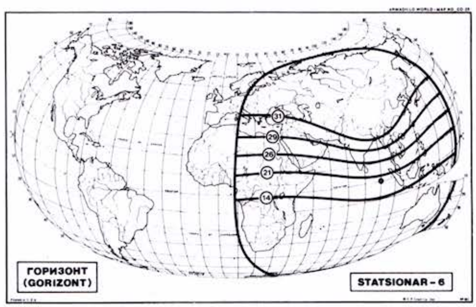


FIGURE 57.

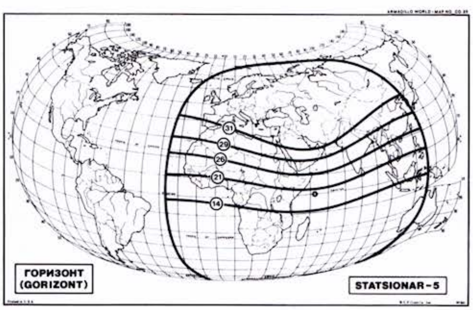


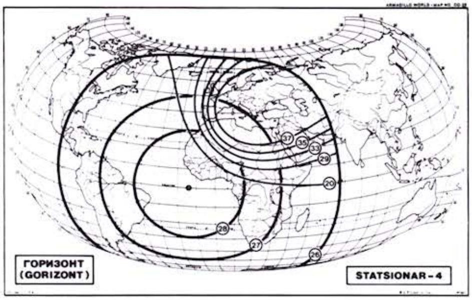
FIGURE 56.

55, built around the excellent NE570/571 compressor-expander chip, with simple active filtering. The Op-amps are type 741 or similar, working between +12V and ground. The bandpass and notch filter component values are likely to require slight trimming to the precise pilot frequency.

OTHER TRANSPONDERS

The GORIZONT C-Band downlinks include the standard global (horn) and hemispheric (sectoral paraboloid) beams. Estimated contours for these are shown in Figs. 49, 56 and 57 for the three GORIZONT locations. In addition there is a beam pattern of EIRP intermediate here between the hemispheric and spot beam patterns, which we think of as a **zone** beam. Now as far as I can determine this is a "half-hemispheric" or larger spot pattern. My estimates are shown in Figs. 58 and 59 for two of the GORIZONT slots, along with the global beam pattern. Assignments of transponders to beams appear to be as Fig. 3. The Atlantic zone beam is used for unilaterals requiring European coverage, but without the high EIRP of the semi-DBS MOSKVA spot beam. Primary and secondary audio channels are on subcarriers at 7.5 and 7.0 MHz, respectively. Occasionally II Programma is shown. The Statsionar-5 zone beam is apparently directed towards Europe, as shown, though the MOSKVA spot beam looks north-east. Reader reports are required to clarify the true nature of these beams.

Channel 10 [9], northern hemispheric (Fig.49) on the Atlantic GORIZONT is a delight to the enthusiast. With 31 to 32 dBW over the whole of Europe it is just marginal on a 3-meter, 100°K system, while a 6-meter antenna will provide good reception in the Caribbean. In common with the other Russian channels it is energized 24 hours per day, the 0167 electronic test card being shown during idle periods. At certain times of the day it takes the I Programma feed, generally including **Vremya** (Time), the



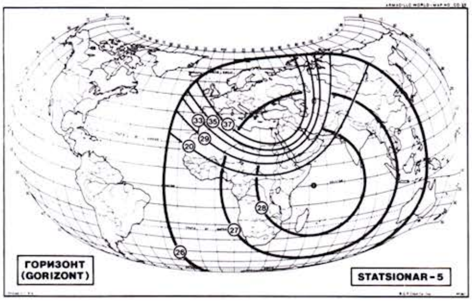
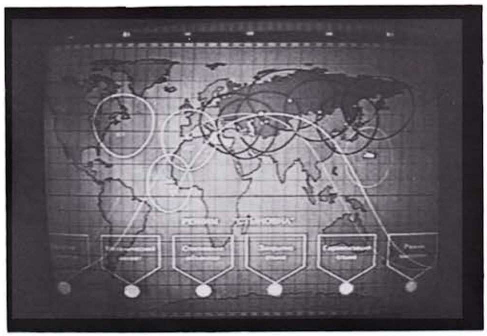
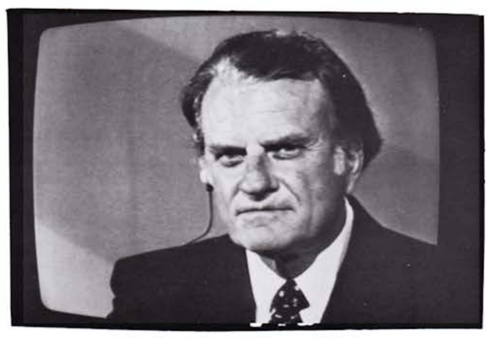


FIGURE 58 & 59. WE DO NOT KNOW THE PRECISE FORM OF THE GORIZONT ZONE BEAMS, **but they may be as shown here, along with the global patterns.**

Moscow 9 p.m. evening news program. Intersputnik unilaterals are also seen, often from Moscow to east European capitals or even to the West. At 1400 London time each day the Dubna control station intercepts the UPITN DSS/E news compilation off the Atlantic Primary INTELSAT, converts it to SECAM color and puts it up on this GORIZONT channel as the first part of an Intervision news exchange that can run for as long as an hour. As soon as the UPITN multilateral finishes, Dubna uplinks Intervision News (IVN) items from Moscow. After that, each contributing country takes its turn to access the bird via its own Intersputnik uplink, and deliver its film and video news snippets. On a typical day Berlin, Warsaw,

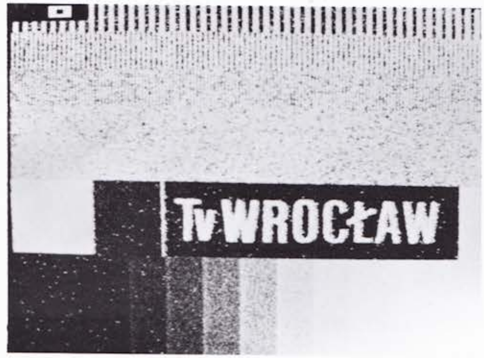


The Atlantic zone beam is used for uilateral transmissions within Europe, like this report for Berlin on the SOYUZ T-6 space flight.



Even feeds for the USA have been seen on this satellite.

Prague, Budapest, Sofia, Bucharest and Havana might all be up in sequence, co-ordinated from Intervision headquarters in Prague. Cuba is always the last in the sequence, and tends to hang on to the transponder after the news feed, reverting to the local 525 line black and white morning show with NTSC color inserts. Moscow



The Intervision News Exchange is a daily feature on GORIZONT hemispheric beam.

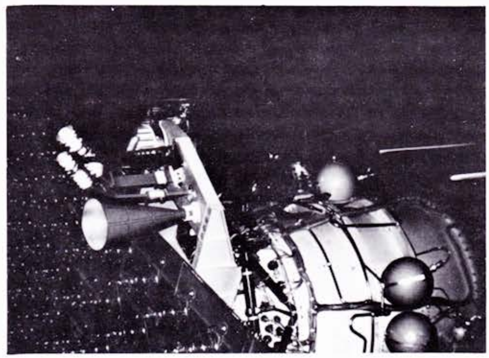
has been seen attempting to remind the Cubans to cut, by keying on and off the Dubna uplink, and carving-up the 525-line picture with their own SECAM test card.

After the Vremya broadcast, from about 2200 Moscow time the transponder often spends a period with the Berlin uplink feeding the DDR-1 or -2 program, though Czech and Polish TV have also been seen at these times, for no apparent reason. After Russian networks close down at 2300-2330 Moscow time there is a period when all three transponders radiate a succession of test patterns. From 0300 in Moscow (1900 in Havana) Cuban TV Nacional (TVC/NTV) Habana canal 6 takes over tpdr 10 [9] most often on Saturdays, 525 lines NTSC, again with 7.5 MHz subcarrier audio. Tele-Rebelde, Habana canal 2, has also been seen.

Now sometimes, but usually Fridays, it seems Dubna's "crazy shift" are on night duty, and you'll see a world of

Polish TV, Cuban Close Encounters, British and German rock shows, are among the Soviet night shift's entertainments.....

...while even Santa Claus has called in to check the uplink.



Part of Ekran's bedspring. Photo Pierre Neirinck, Paris 1977.

un-Soviet material on this channel. They have a collection of taped "goodies" lifted from Europe's TV services, as well as some dubious material on videocassette. It starts around midnight Moscow time, with recent editions of Radio Bremen TV's "Musik Laden" or BBC's "Top of the Pops". Whoever directs this material to Dubna has a "trade mark" of 8 question marks inserted in a rectangle at the corner of the frame. He also likes Bugs Bunny cartoons. When they tire of this, they can usually locate a Bruce Lee style martial arts movie to uplink, in English with Dutch or Spanish subtitles. On one recent occasion they had a black and white camera trained on a circuit schematic for an hour, with their conversations audible on the sound channel!

EKRAN

The 620-790 MHz band was accorded footnote status at WARC-71 for direct broadcast service within certain constraints, in Regions 1 and 3. The Soviet Union chose this frequency band to inaugurate their DBS TV service to remote communities in the far north of Siberia, where there is no terrestrial UHF TV, and filed for an orbital slot, Statsionar-T (for Television) at 99°E.

The system, and its satellite, were called EKRAN (Screen). First launch was in 1976 and most recent (No.8) in 1982. Even allowing for an on-orbit spare, they don't last long. Uplink is at 6.2 GHz and downlink in a 24-MHz wide channel centered on 714 MHz and aimed at the satellite's northern horizon, in which direction it delivers 56.5 dBW with right-hand circular polarization. Two 200-watt Klystrons provide the RF power, to a "bedspring" array of 96 phased helical elements. Video is transmitted in standard wideband FM format, though with reduced deviation (9 MHz peak video) compared to the 13 MHz of the Orbita and MOSKVA channels, and audio is conveyed by 6.5 MHz subcarrier.

Program is **Orbita-III**, as Moscow **I Programma** but 4 hours ahead, for northern central Siberia. The solid line contours of Fig. 60 are as published by the USSR, the broken lines represent an estimate of the off-boresight pattern, on the evidence of reports from South Africa, Malawi, the Middle East, India and Sri Lanka, and of complaints from China. The uplink and control station is at Gus'-Khrustal'nyi, near Moscow.

The Soviet EKRAN TVROs employ broadside stacked arrays of helically-fed crossed yagis, giving 21 or 28 dBi gain (two types) together with a bipolar LNA of 2.5 dB noise figure. The higher gain EKRAN receiver is used at

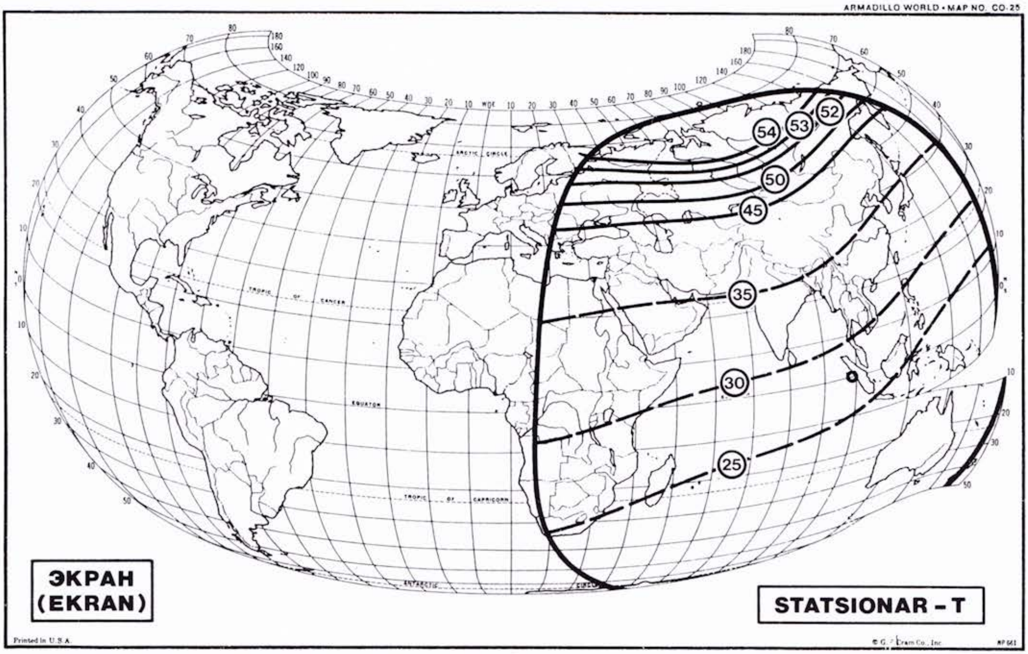


FIGURE 60.

C

Orbita-III via EKRAN at 714 MHz strays into South Africa, with a little persuasion. Photo Ian Roberts.

stations which rebroadcast the signals terrestrially, the lower grade is for individual reception and small community cable systems.

FUTURE SOVIET SATELLITES

The Russian plans are running some two years behind their original projections, with some priorities having been reshuffled. Promised Statsionar slots 7-10 remain to be activated, and the LUCH (Beam) 11 GHz system has not yet materialized, although this year's Kosmos-1366 may be an experimental precursor. A new class of telecommunications satellite, POTOK (Stream) has been heralded in Soviet publicity.

OTHER DOMESTIC SYSTEMS

PALAPA

Indonesia has special telecommunications needs. An archipelago of over 13,000 islands, 5,000 being inhabited, spread over a region 3,000 by 1,500 miles wide, the nation saw a satellite system as the only way to meet its development requirements for communication and educational services. The domestic system, PALAPA, began operation in 1976 with 25 ten-meter earth stations and an HS-333D dual spin-stabilized satellite similar to the WESTAR and ANIK A series. A second HS-333D was launched the following year, and both are still in operation (Fig. 61). The development plan called for forty ten-meter terminals of heavy and light traffic classes, plus a number of small (4-meter) terminals. Principal traffic is telephony, initially 2124 FDM/FM channels, 225 SCPC demand-assigned channels and 40 SCPC permanently assigned channels. The 10-meter terminals downlink one TV channel, uplinked by Jakarta or Surabaya, to be rebroadcast locally on terrestrial VHF. Since 1976 the service has expanded rapidly to full capacity on the two satellites (24 transponders in all), with earth station count approaching 100, and channels leased to neighboring Malaysia, Thailand and the Philippines.

PALAPA is the name of a national fruit delicacy, which for historical reasons came to symbolize the unification of the Indonesian nation. The PALAPA satellite system in

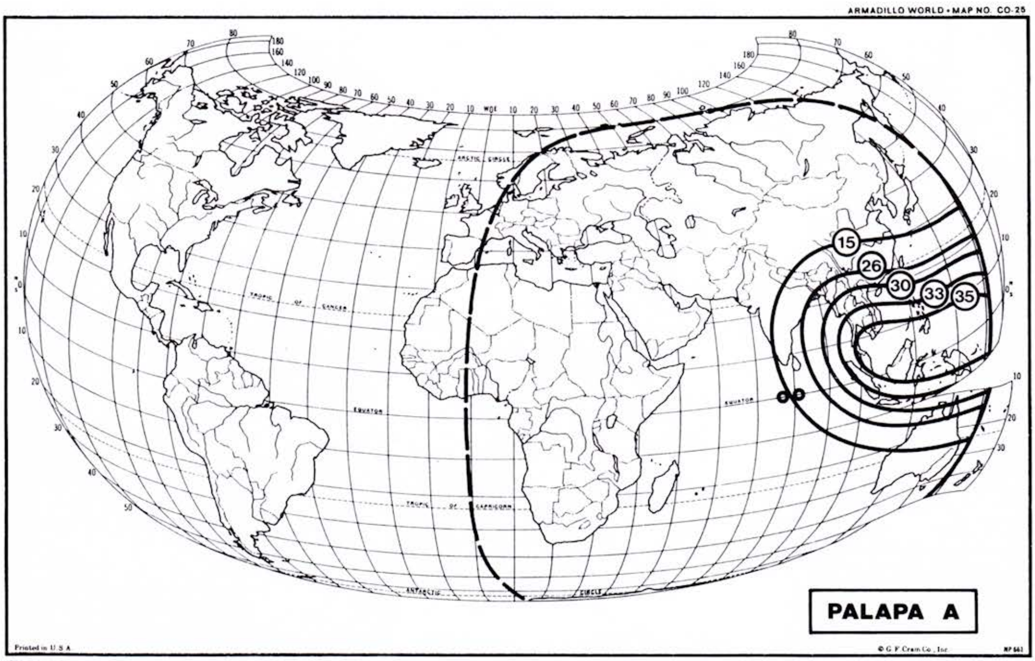


FIGURE 61.

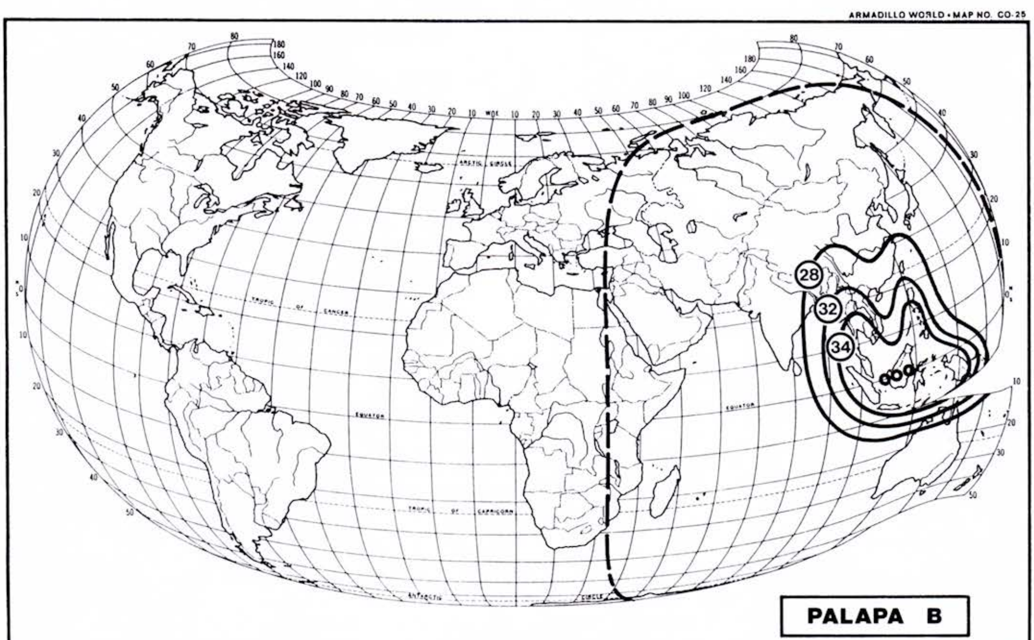


FIGURE 62.

fact serves the Association of South-East Asian Nations, ASEAN, including Singapore, Malaysia, Thailand and the Philippines. With the saturation of the two-satellite system and the limited life expectancy of the original birds, Indonesia has acquired three new PALAPA-B satellites, based on the Hughes HS-376. These will be 24-transponder C-Band birds similar to ANIK-D and the latest WESTARS (Fig. 3) and will have footprint shape optimized to deliver 32 dBW minimum over the entire ASEAN region and 34 dBW over Indonesia (Fig. 62). PALAPA B-1 is scheduled for Shuttle launch in April 1983, to 108°E. The broken line on Figs. 62 and 63 represents the limit of visibility. EIRP is not specified towards edge-of-earth except within the PALAPA A footprint, and visibility can not be taken to imply usability.

Indonesian TV was originally allocated to PALAPA A-1 transponder 8 [15] with tpdr 11 [21] as a backup. 9, 10 and 12 [17, 19 and 23] were to be available for lease. I have little information on the current TV traffic, but it is believed that the Malaysian, Thai and Philippine leases are used for TV relay. Format is full transponder with subcarrier audio, Philippines TV is 525 lines NTSC, the others being 625 lines PAL. Northern parts of Australia report adequate reception on 12 foot, 120°K systems, while Papua New Guinea is within the primary service zone and excellent results are obtained from a 3-meter antenna.

A study of the predicted PALAPA B footprint (Fig.62) suggests strong possibilities for TVROs in the 6-meter class as far out as South Korea and southern Japan (Kyushu), Sri Lanka, eastern parts of India and the northern half of Australia. Hong Kong and Taiwan (Formosa) are within the 28 dBW contour. Here a 4.5 meter installation should give excellent results. Reception reports please!

INSAT

Among the objectives of the Indian National Satellite System (INSAT) is the continuation of the rural educational program begun in the 1975/76 SITE experiment, when NASA's ATS-6 satellite with its UHF DBS payload was made available to India.

For the operational community DBS, the downlink has been changed to the arguably more suitable 2.50 - 2.69 GHz (S-Band) allocation, with two 50-watt 36 MHz channels centered on 2575 and 2615 MHz, delivering a minimum of 42 dBW towards the edge of the defined service area (Fig.63) with left-hand circular polarization.

Other INSAT objectives include C-Band domestic communications and meteorological data services. The Met package includes remote data collection, uplinking at 400 MHz, and very high resolution radiometry (earth imaging) at visible and infrared wavelengths. These all share the 4 GHz downlink (Fig.3) with a 14 MHz band reserved for telemetry and the auxiliary services, between channels 8 and 9 [15/16 and 18].

Otherwise the transponders follow normal domsat practice, with 36 MHz nominal bandwidth, horizontal polarization and full-transponder TV capability. Specification EIRP is 32 dBW minimum over the primary coverage zone and real-world value is expected to be as high

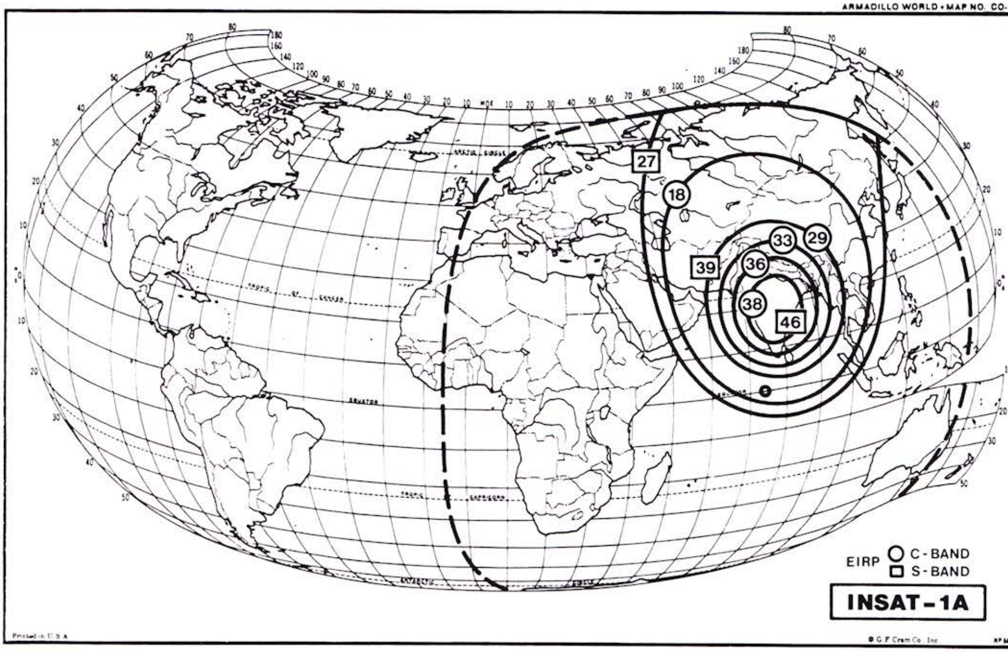


FIGURE 63

The Satellite Instructional Television Experiment delivered DBS television to India in 1975. INSAT has now taken over where ATS-6 left off but, unlike ATS-6 it cannot be seen from the UK.

as 39 dBW at beam center.

Two satellites have been procured from Ford Aerospace. The first was launched in 1982 to 74°E and, after some difficulty with solar array and C-Band antenna deployment, is now reported to be performing satisfactorily. It is now rumored to have failed. INSAT-1B is expecting to be launched at 94°E during July 1983.

The Master Control Facility for the INSAT system (at Hassan, near Bangalore) is equipped with two 14-meter antennas for simultaneous operation of both INSAT spacecraft. Main communications stations are similar to INTELSAT "B" standard, 12-meter antennas giving a receive G/T of 31.7 dB/K. Primary stations are 8 meters with 150°K system noise temperature, and remote stations are 4.5 meters, 190°K. Community DBS TVRO terminals are of open-mesh construction 12-foot aperture, with 760°K noise temperature at S-Band (G/T 7.2 dB/K). All-India Radio's TV service is understood to be relayed at C-Band as well as on the S-Band DBS. India has chosen the PAL color system, but color service has not yet begun and transmissions are 625 lines black and white.

APPLE, the Ariane Passenger PayLoad Experiment, also known as ISCOM-1, was an experimental precursor to INSAT, launched on an Ariane test flight in 1981. This limited capacity bird, over 105°E, carries a low EIRP C-Band transponder but its utilization is not thought to include regular TV transmissions.

ARABSAT

The Arab League's regional communications satellite project has been under discussion since the late 1960s. The ARABSAT organization was formed in 1976, and in 1981 the Arab states were able to agree to place the space segment contract with French company Aerospatiale, with Ford Aerospace as subcontractor, to deliver 3 ARABSAT spacecraft (two operational plus one spare). The first launch is planned for early 1984 to 19° E followed a year later by ARABSAT-2 at 26° E.

In many ways ARABSAT is a big brother to INSAT. C-Band capacity will be 25 transponders of 33 MHz each, employing frequency re-use by dual orthogonal circular polarizations. But ARABSAT will have a similar S-Band payload to INSAT, broadcasting TV programs directly to small communities via two **33 MHz** channels at 2560.5 and 2634.5 MHz, this time with **linear** polarization and a beam-edge EIRP of 41 dBW minimum.

20 nations make up the Arab League: Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates, Yemen Arab Republic and Yemen People's Democratic Republic. The PLO has observer status. The ARABSAT objective is to provide Arab League coverage. I have not seen a footprint projection, but it can be seen that a shaped beam similar to Fig. 64 would provide the required Pan-Arabian pattern at C-Band. I must stress this is only guesswork at this time to aid estimates of where Arab television reception **might** prove possible, and I will publish the actual footprint data, should it become available, in one of our updates. Minimum C-Band EIRP has been specified as 31 dBW, to serve major earth stations of 11-meter aperture (G/T of 31.7 dB/K) and TVROs of 4.5 meters. S-Band community TVRO specification is 11 dB/K at 2.5 GHz, which could be achieved with a 3-meter antenna and 200°K LNA.

With the inauguration of ARABSAT, it seems probable that those Arab nations with domestic systems already operational on INTELSAT will terminate their leases, in favor of ARABSAT capacity. These could include Algeria, Morocco, Oman, Saudi Arabia and the Sudan. A consequence or this would be the contraction of present hemispheric and global coverages to rather more economical size, with higher EIRPs within the target countries but loss of service "off-boresight". It could happen as soon as 1984. A definite footprint prediction will enable us to determine the requirements for continuity of service.

SATMEX

C-Band domsat system for Mexico. Satellites to be called Ilhuicahua, located 85°W and 102°W. Not before 1985.

SATCOL

C-Band domsat system for Colombia. 24-transponder birds, minimum EIRP 35.6 dBW over Colombia. Locations 75.4°W and 70°W. First launch expected mid-1984.

BRASILSAT (SBTS)

C-Band domsat system for Brazil. 24-transponder HS-376-type spacecraft. Locations 70°W, 60°W, 65°W, to be verified. First launch expected mid-1985.

AUSSAT (ANSCS)

Australian National Satellite Communications System. Completely different. A **Ku-Band** domestic system planned for 1985, based on Hughes HS-376 bus, covering Australia and offshore islands with multiple beam patterns in 15 transponders including **medium power DBS** and **low power FSS** transmission. First of three launches planned for 1985. Downlinks 12.25 to 12.75 GHz, dual linear polarizations.

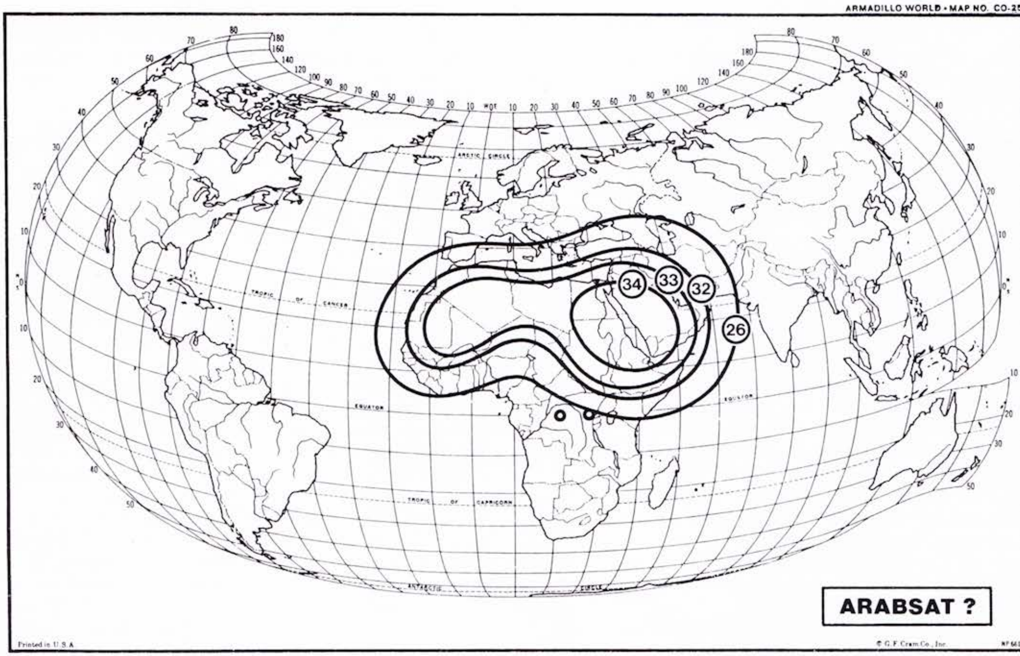
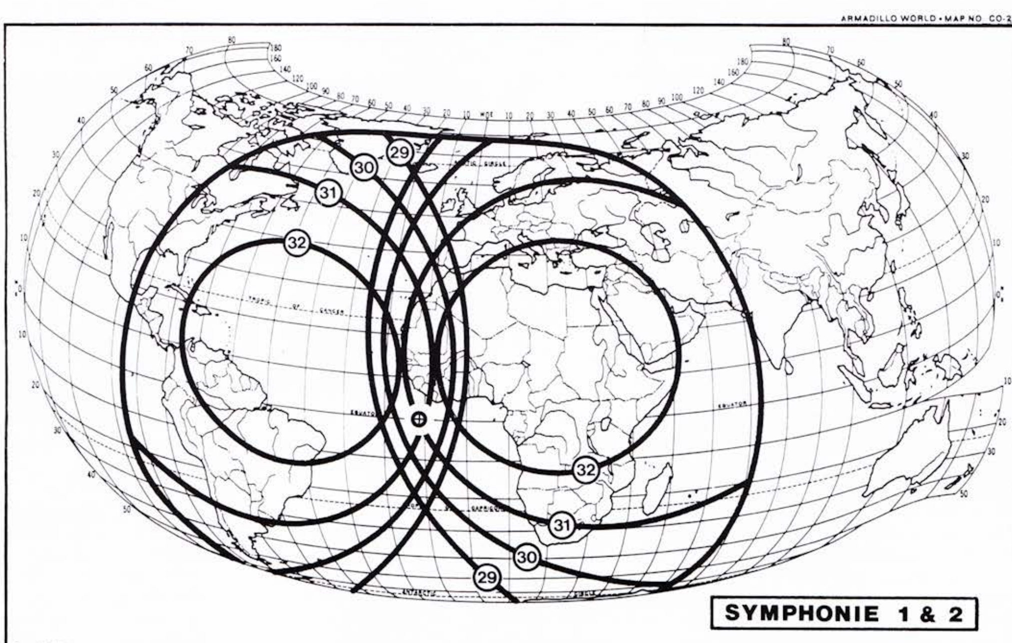


FIGURE 64. NOW YOU KNOW WHY WE CALL 'EM FOOTPRINTS. This is the type of Pan-Arabian beam which Arabsat will be called upon to illuminate in 1984.



SYMPHONIE

The two SYMPHONIE satellites were the result of a very successful collaboration between France and the German Federal Republic. Essentially designed as technology test-beds, the two birds have more than fulfilled the most optimistic expectations of their designers, both in performance and operation. Nominal life was five years from launch dates of December 1974 and August 1975, and both spacecraft are still in everyday communications service.

Original system plan was for the two satellites to share a geostationary slot at 11.5°W. This they have done for most of their lives, though the F1 bird spent a period at 49°E, providing experimental service to India and Iran. To make best use of spectrum space the transponder bands on the two satellites are interleaved, giving a total of four 90 MHz channels (Fig.3). Otherwise both spacecraft are identical. They are now co-located again at 11.5°W over the Atlantic.

The two transponders on each SYMPHONIE satellite are selectable to two spot beam antennas, looking east and west of the subsatellite point. They are similar to INTELSAT IVA hemispheric beams, but without the beam shaping and inter-beam isolation. Fig. 65 shows EIRP contours at beginning of life, some 2 dB above specification. Saturation power may by now have fallen somewhat; figures are not to hand.

The two primary SYMPHONIE stations are at Pleumeur-Bodou in France and Raisting in Germany, but many countries have been involved in the SYMPHONIE program of experiments, amounting to over 40 terminals ranging in size from 16 meters down to 4 meters fixed and to 2.2 meters mobile. The continuing operational use involves daily communications between Germany or France, and stations in the Indian Ocean, Africa, North, Central and South America.

Most accessible is the nightly relay of TF1, France's principal TV channel, to the French sector of West Berlin and to the island of LaReunion in the Indian Ocean. This is currently transmitted at 4170 MHz [24] in channel "d" of the F1 bird, eastern spot beam. EIRP is backed off somewhat to accomodate SCPC communications at the low end of the channel, including the German overseas radio service Deutsche Welle, two channels around 4105 MHz. TV EIRP is estimated about 3 dB below Fig. 65.

The other interesting TV service is a daily one-hour news transmission at 1600 Paris time, for St Pierre et Miquelon (off Canada's east coast) and French territories in and around the Caribbean. This is downlinked near 3980 MHz [14] in F2's transponder "c", west spot, and is parallel fed on INTELSAT (tpdr 12 [24] of the Atlantic Primary at 24.5°W). Both these SYMPHONIE TV transmissions are (36 MHz) "full transponder" deviation, 625 lines SECAM, with audio on 6.3 MHz subcarrier.

Various other carriers can be found on SYMPHONIE. One curious transmission is associated with an experiment in electronic clock synchronization, and takes the form of a non-standard 625-line TV waveform of narrow deviation, containing a one-second recurring pulse. This has been seen in more than one transponder and beam.

Some explorers have had difficulty finding signals from SYMPHONIE, or have found them by accident with a mis-aligned mount. The reasons are two-fold. Firstly, **left-hand circular polarization** is used on the downlinks. And secondly, SYMPHONIE is **not in geostationary orbit**. Geosynchronous yes, but stationary?

It is generally assumed that a stabilized "geostationary" satellite appears perfectly fixed in the sky. But that is an ideal never fully realized. The North American domestic satellites are **virtually** stationary. With their ±0.1 degree stationkeeping "box" they don't move more than 70 kilometers in any direction from "home". That's near enough stationary for all but the very largest (15-meter plus) antennas, at 4 GHz.

The SYMPHONIE system was originally designed for north/south and east/west stationkeeping tolerance at least as good as ±0.5°, with the option of going to ±0.1°. With the spacecraft approaching end of nominal life and the possibility of total depletion of fuel, stationkeeping regime was relaxed. As a result, both spacecraft now have an **orbital inclination** of about three degrees, manifested as an apparent daily motion north and south of the equatorial plane, following a slim "figure-eight" curve. In practice this means the earth stations need to track the satellite, mainly in declination, over the 24-hour period. The two SYMPHONIEs have remained in near phase synchrony in their diurnal motion, simplifying operations considerably. A typical tracking polar mount TVRO has limited declination adjustment, and if at the time of day the search is conducted the satellites happen to be three degrees out of the orbital plane they will probably be **missed entirely**, despite high EIRP. Given an antenna system motorized about **two axes**, SYMPHONIE can provide French TV to 4.5 or 6-meter terminals throughout Europe, Africa and the Middle East.

French TF1 is available at high EIRP over a wide area via SYMPHONIE.

Fig. 66 shows the actual ground-track shapes for two values of inclination angle, i. At left is the "figure 8" curve resulting from 30° inclination of the circular orbit. Over the 24-hour period (actually 23 hours 56 minutes or so, allowing for the earth's rotation) the satellite swings northwards as far as 30°N, then southwards to lat. 30°S, crossing the equator once in each direction. Six hours

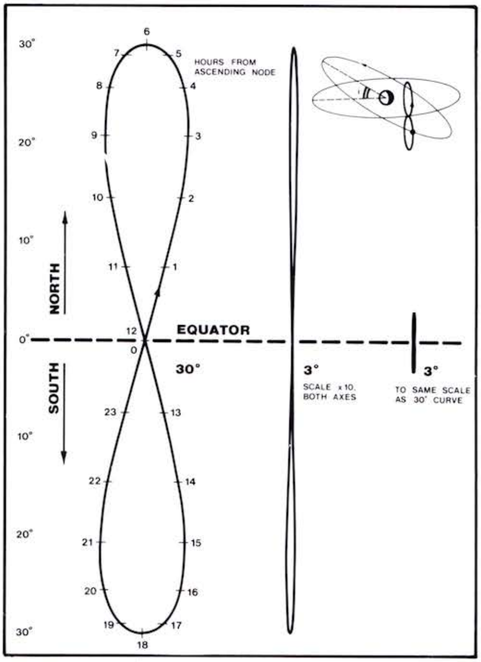


FIGURE 66. WE SPEAK OF "THE FIGURE-EIGHT CURVE" BUT FOR LOW VALUES OF ORBITAL INCLINATION IT IS TO ALL INTENTS AND PURPOSES A STRAIGHT LINE.

from northbound equator crossing (ascending node) it appears slow-moving near its most northerly point, and twelve hours further on it reaches southern apex. The figures along the curve show hours from ascending node, giving an indication of relative velocity of the sub-satellite point.

Now look at the right of Fig. 66. To the same scale I have drawn the "figure 8" curve for a satellite like SYMPHONIE with a 3-degree tilt to its orbit. It looks just like a short vertical (here north-south) line. To make things clearer I've increased the scale by a factor of ten and re-drawn the curve at center. Now the north-south motion looks the same as for 30° inclination, and it can be seen that the east-west motion is very much less in proportion. In fact for three degrees inclination of a circular orbit the east-west component is less than ±0.04 degrees in longitude. Translate this ground track to look angle coordinates, and it works out that for all practical antenna sizes the "figure 8" requires tracking in **declination alone** - it is so narrow that it can be regarded as a straight north-south line. Look angle geometry requires declination tracking of a little more than the peak-to-peak inclination value near the sub-satellite point, and away from the meridian an el/az mount requires tracking about both axes, as can be seen from the "sky chart", Fig. 67, for my own location. Tracking rate for 3° inclination is always less than 1 degree per hour. A step-track system could be devised, monitoring signal level on a suitably long integration time and taking exploratory action in a predetermined sequence whenever the level falls by more than say 0.5 dB. Such an automatic tracking program is built into Russia's unattended MOSKVA terminals.

Incidentally, I find this plot (Fig. 67) a useful aid to appreciating the MOLNIYA look-angle geometry. Turning the page round to place the northern horizon towards you and looking up past Polaris, the North Star, towards the zenith, the Molniya "sky tracks" can be seen at north-west and north-east. These look very different in North America and central Asia where the MOLNIYAs pass directly overhead.

TELECOM-1

SYMPHONIE having proved its operational worth, the French have retained some of the system's features in their multipurpose TELECOM-1 system based on the OTS bus and due for first launch in 1983. SYMPHONIE is expected to remain operational at least until TELECOM-1A is available.

TELECOM-1 provides the link between our treatment of world-wide domestic and regional systems, and the European 11/12 GHz sector, since it is a part of both. The C-Band payload will take over from SYMPHONIE to provide telecommunications with French overseas territories, and a 12.5 GHz (downlink) digital business services package will join that of ECS-2 as the first of their kind in Europe. A third communications payload will meet the requirements of France's SYRACUSE military mission with two 20-watt, 40 MHz channels, global coverage in 8/7 GHz X-Band.

Like SYMPHONIE, TELECOM-1 fields four wide-band transponders at C-Band. But now two are of 120 MHz usable bandwidth, while two are a more conventional 40 MHz. One of the 120 MHz transponders serves a spot beam footprint illuminating the French Antilles, Guadeloupe and Martinique and as far south as French Guyana with an edge EIRP specification of 35 dBW. The other three channels are connected to a shaped semi-global beam (Fig. 68) delivering a minimum of 26 dBW over Africa, Reunioon, St Pierre et Miquelon and the Caribbean, with a central EIRP of 28.5 dBW minimum towards France. TWTA power is 8.5 watts. Polarization, like SYMPHONIE, will be left-hand circular.

In the band 12.50 - 12.75 GHz (downlink) TELECOM-1 will have six 36 MHz transponder channels (Fig.5). One of these will be dedicated to TV relay "for professional, cultural and educational purposes", the other five to high bit rate TDMA (Time Division Multiple Access) digital data communications, between antennas as small as 3.5 meters in metropolitan areas. Design EIRP is 47 dBW to France and neighboring countries, 44 dBW over much of western Europe, the secondary service zone (Fig. 69). 12 GHz TWT powers are 20 watts nominal, the TWTAs and the spacecraft itself being derived from the OTS design.

Among regional systems, TELECOM-1 is unusual in having published off-boresight EIRP contours (Fig. 70). These are derived from antenna tests at France's La Turbie facility, and show the kind of relative levels that might be expected towards Africa and Canada, from similar European 12 GHz spot beams. 10 dBW is 40 dB down from a boresight of almost 50 dBW, but consider a future European DBS with a maximum EIRP of say 68 dBW. Assuming a similar antenna pattern, north-east

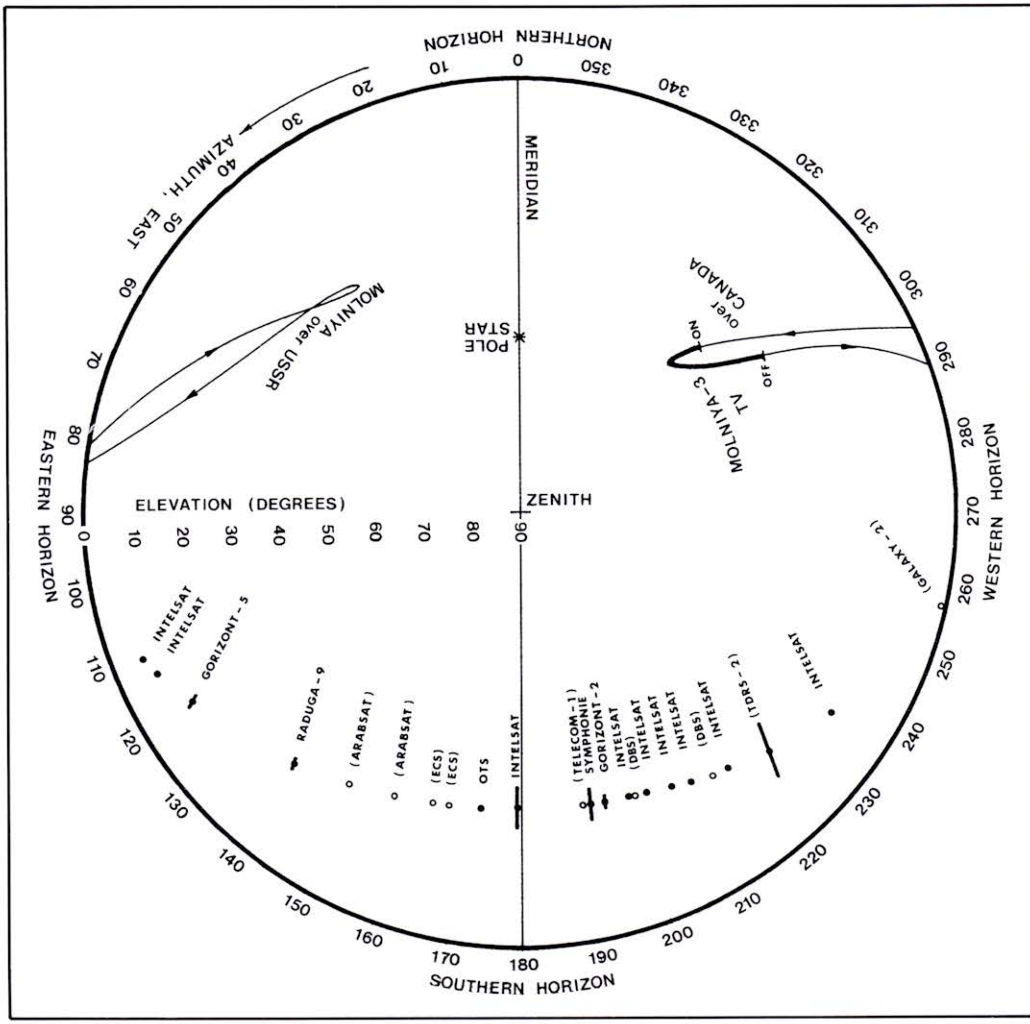


FIGURE 67. THIS I CALL A SKY CHART. It's the view looking straight up from the antenna towards the zenith, with the horizon all around. As you turn it round, always look at the half nearest you and things will seem the right way up. If you have any obstructions (such as trees, buildings or mountains) you can draw them in around the periphery of your own chart, having measured how much sky they block, as seen from the antenna.

Canada could see 28 dBW. Not exactly DBS-type level, but given a 6-meter antenna and 3 dB receiver noise figure....

EUROPEAN 11/12 GHz DOMESTIC and REGIONAL SYSTEMS

SIRIO-1

This Italian experimental bird carried the first European 11 GHz downlink, in 1977. Primarily to test propagation from geostationary orbit at these frequencies, it flies a wide-band (well, 26 MHz, see Fig. 5) communications transponder capaable of relaying TV. With a beam-center EIRP of 29.5 dBW steerable to western Europe or the North Atlantic, it didn't exactly set the treetops ablaze but it did provide valuable experience prior to the launch of OTS, and was a total success for Italy. Its nominal lifetime was spent over 15°W from where it yielded below-threshold but identifiable pictures on my own 8 ft. terminal on the few occasions I found it carrying TV. It has since been retired (according to the tracking agency) to 24.5°W. I don't know whether the wideband transponder is

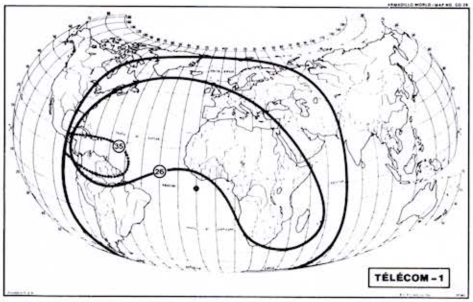


FIGURE 68. TELECOM-1's 4 GHz coverage zones. The banana shaped footprint has a highlight zone of 28.5 dBW (minimum) towards France.

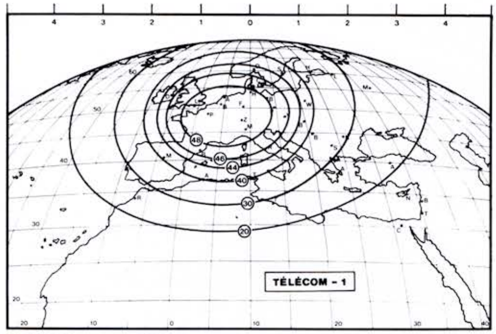


FIGURE 69. TELECOM-1, 12.5 GHz European business services.

ARMADILLO WORLD • MAP NO. CO-25

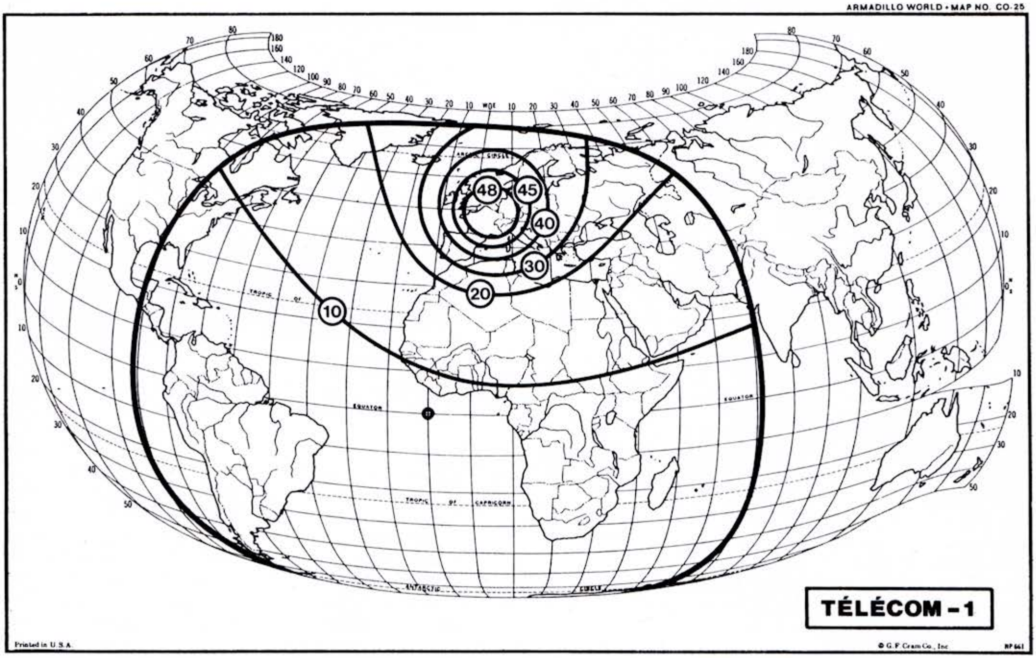


FIGURE 70. TELECOM-1, Off-boresight EIRP for 12.5 GHz down- links.

still operative but its use would seem unlikely since it now appears to share an INTELSAT location, and its downlink frequency lies within the INTELSAT V 241 MHz slot 7-12 serving the European spot beam from 24.5°W. As I write, SIRIO-2 was due to orbit but has been lost due to failure of the first commercial flight of Europe's Ariane launch vehicle. SIRIO-2 did not carry the same type of communications payload as SIRIO-1, and a replacement is not expected.

OTS

Really, any discussion of European Ku-Band TV operations should start with the **Orbital Test Satellite**. OTS is the pre-operational test vehicle for the **European Communications Satellite** project. Built by the MESH consortium of European industry in the mid-70s, it pioneered much of the technology for subsequent 11/12 GHz FSS and DBS programs, both in space and on the ground. The first OTS was lost in 1977 when its Delta launch vehicle exploded, and a second flight model was readied in time for a successful orbit insertion in May 1978. That explains the persistent references to OTS-2, when in fact OTS-1 never operated.

OTS experiments have covered almost every aspect of satellite communications, including point-to-point, TV outside broadcast, simulated DBS, videoconferencing, data relay and small terminal telephony links. Valuable data has been gathered on space/earth propagation at

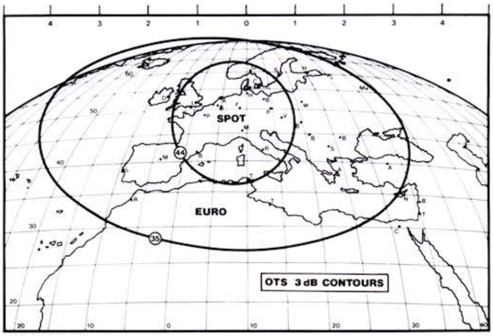
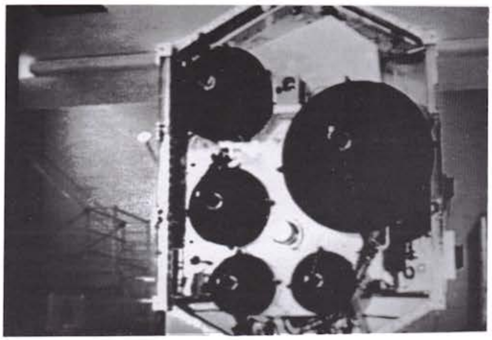


FIGURE 71.



The Orbital Test Satellite, seen here in a European Space Agency film transmitted via OTS itself.

Ku-Band frequencies in the European climate, with particular regard to fading depths and atmospheric depolarization. The validity of dual polarization principles has been proven.

Six transponders make up the OTS payload, together with beacon transmitters. Two are narrow band channels (5 MHz bandwidth), and the remainder are 40 MHz or 120 MHz nominal (Fig. 5), with performance specified over 36 MHz and 108 MHz. The two 40 MHz channels share a frequency, using orthogonal linear polarizations, and downlink via an elliptical "Eurobeam" (Fig. 71) encompassing the whole of the European Broadcasting Area (with the exception of Middle-Eastern regions), extending to Iceland and northern Africa, at a beam-edge (-3 dB) EIRP of 35 dBW. In fact the footprint is specified out to -6.5 dB, an EIRP of 31.5 dBW which takes in the Azores and Canary Islands, all of North Africa and part of the Arabian peninsula.

The 120 MHz channels serve a spot beam pattern, centered near Bern in Switzerland, with some 47 dBW EIRP at beam center. Again in Fig. 71 I have shown the -3 dB contour, but Fig. 72 tells a more complete story. This is for nominal beam pointing - the OTS spot beam has in its time been slewed for certain tests and demonstrations, by biasing of the spacecraft's attitude control.

A degree of redundancy was built into the communications package, but one of the 20 W TWTAs, that serving

The European Broadcasting Union has conducted several series of experimental broadcasts via OTS.

horizontal channel $\overline{2}$ (two bar) failed with no backup, putting that channel out of action. The other three wideband transponders are fully operational and in everyday use, despite the spacecraft having already exceeded its three-year nominal service lifetime. Sufficient expendables were carried for 5 years life with ±0.1 degree stationkeeping, and this figure looks like being achieved.

For spot beam TV transmission the full 120 MHz bandwidth is not used. Standard TV channel widths are 40 MHz ("Eurovision Format") and 27 MHz ("DBS format"). The latter is employed for TV relay to Cable systems. When the highest transmission quality has been required for broadcast relay of two channels, frequencies have been offset in opposite directions from the 11.64 GHz transponder center frequency, to reduce to zero the already small probability of co-channel interference between the cross-polarized signals.

The first full-time television service on OTS was a nightly relay of France's commercial second program, Antenne-2, to French-speaking Tunisia. Kabel Televisie of Amsterdam saw its potential, installed a 3-meter terminal and began relaying the French programs to its 300,000 subscribers. French TV didn't object - here was extra advertising revenue. But the Dutch telecommunications authority took a hard line, the Dutch government

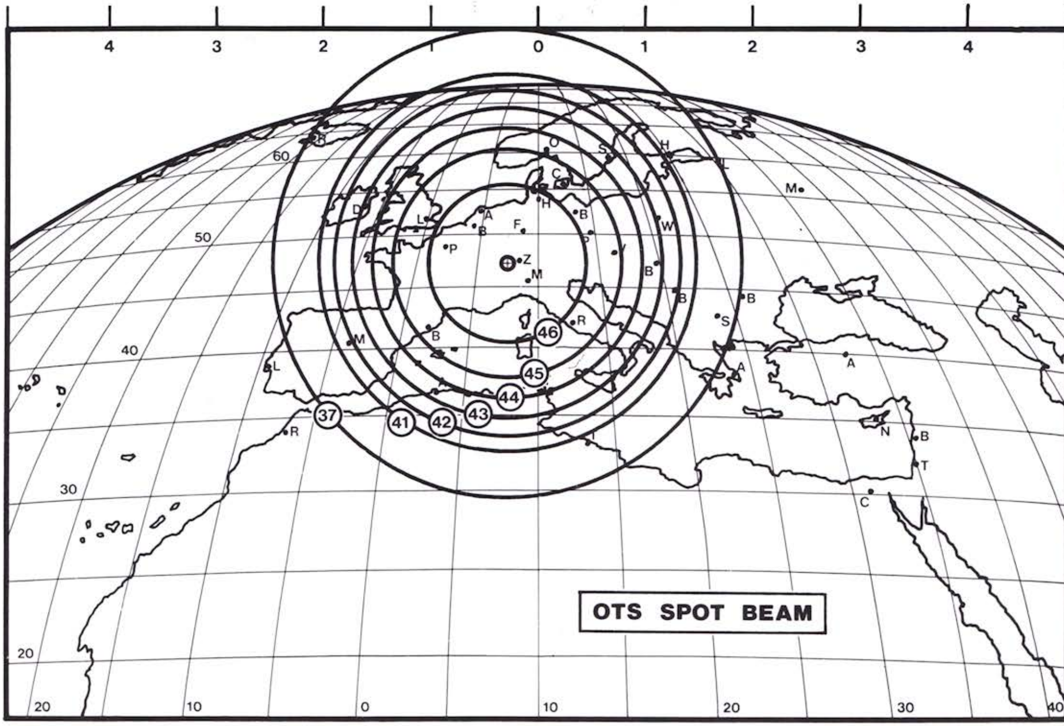
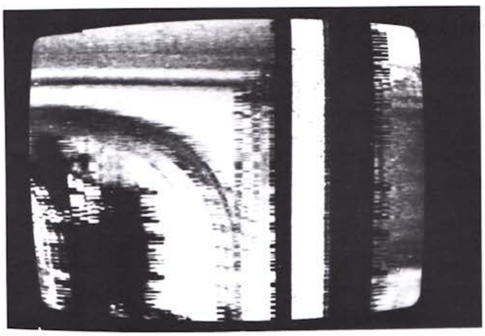


FIGURE 72.



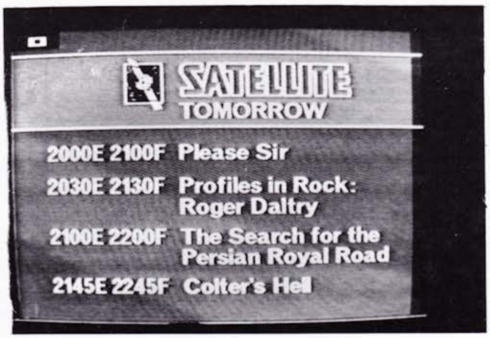
A line-displacement form of scrambling, with standard sound-in-syncs, is used for the French TV feed to Tunisia via OTS.

The Programs of "Satellite Television" use Oak "Orion" encryption, where syncs are suppressed and even the digital audio is scrambled.

already being sensitive about foreign cultural invasion, largely by television. Representations to Eutelsat, the OTS governing body of which the French PTT is a member, brought pressure to bear on the French broadcasters who were obliged either to cease the Tunisia feed or to scramble it. They chose scrambling, effectively killing the program's Dutch Cable relay.

Eutelsat's insistence on scrambling to prevent unauthorized use has persisted, and the British company Satellite Television had to follow suit when their full service began in the spring of 1982. At present, Satellite Television transmits some two hours per evening (1900-2100 London time) of entertainment programming in English, with advertising, to Cable TV operations in continental Europe and the Mediterranean, via the OTS spot beam.

Satellite Television occupies transponder $\overline{4}$ ("horizontal" polarization) with 625-line PAL color. Scrambling is the PAL Version of the Oak "Orion" system, which replaces sync pulses by a burst of sine-wave at mid-video frequencies, with optional random luminance inversion. Audio uses digital "sound-in-syncs", digitally scrambled.



The addressing facility is not here exploited. The French TV transmissions are 625 lines SECAM in transponder 4 ("vertical") and scrambling employs line displacement by one or two one-microsecond delays, switched according to a time-varying pseudorandom sequence. Sound-in-syncs audio is not scrambled. The Orion video is relatively easy to descramble, but its digital audio has a higher security.

The OTS 3-dB down contour encompasses all of Germany, France, Austria, Switzerland, Denmark and the Benelux countries, most of England, Wales, Scotland and Italy, southern regions of Norway and Sweden, much of Yugoslavia, and extends to Tunis in North Africa. Within this region Cable TV grade service is assured with a 3-meter antenna and an LNC in the region of 4 dB noise figure. In the central zone an antenna as small as 1.5 meters will provide a service, while a 6-meter installation will give Cable grade reception out to the 37 dBW contour. Marginal performance, good enough for individual reception, can be achieved 3 dB further out from boresight with the TVROs in these examples.

One constraint facing those who specify such systems is the limited lifetime of OTS. ECS-1 was due for launch at the beginning of 1983. With the Ariane failure coming during the final typing of this manuscript it seems likely that the launch schedule will be put back. OTS has already been moved to 5°E from its original location at 10°E, now claimed by ECS-1, and Cable services are looking towards relocation to ECS during 1983. OTS promises to remain serviceable thorugh 1983, but ultimately any service will face closure or transfer to ECS. But as we shall see, there are differences between the OTS and ECS footprints which must be taken into account.

ECS

The design of the European Communication Satellite system has evolved since OTS flew. The biggest change was to transponder bandwidth. Since 40 MHz and 120 MHz were proposed, there has been some standardization on a bit rate of 120 Mb/s for digital (including TDMA) systems. The European PTTs' proposed digital formats can most economically be handled by a transmission channel of 80 MHz bandwidth, or a little less. Accordingly, the ECS plan was changed to accommodate twelve transponders, each of 72 MHz usable bandwidth. As on OTS, frequency re-use by orthogonal linear polarizations is employed, that is six transponders on each of two polarizations.

A second change was to the beam pattern (Fig. 73), where instead of one "Eurobeam" and one spot beam, a total of three spot beams are furnished in addition to the Eurobeam, giving improved service to small terminals in the dense telephony traffic zones. These spot beams are

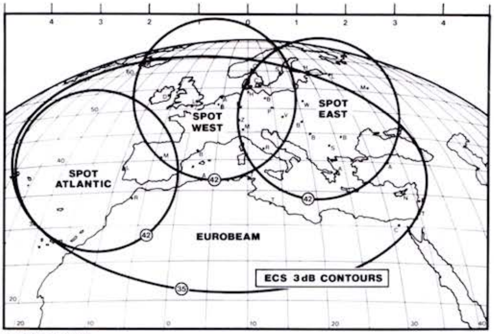


FIGURE 73.

larger than on OTS, and with the same TWTAs of 20W saturated output power this means boresight EIRP is some 2 dB lower than the OTS beam. Transponder/beam assignments are shown in Fig. 5.

Another innovation is the provision of a pair of "multi-service" transponders downlinking in the European business services band 12.5 to 12.75 GHz. These are included on ECS flight 2 and subsequent satellites, and share the uplink frequency of channels 4 and 10 (otherwise 4X and 4Y) on an either/or basis. Footprint is similar to the Eurobeam, but with a beam center EIRP of 43 dBW, requiring a 4.5-meter earth terminal for 24.576 Mb/s digital TDMA communications. A hierarchy of lower density traffic is proposed, down to 64 kb/s SCPC, which is capable of being uplinked by no more than 1 watt to a 4-meter antenna.

With regard to transponder allocations, the system's capacity has been jealously guarded by the PTTs forming Eutelsat. Initially only two ECS-1 transponders were allocated to television, on Eurobeam for EBU use as part of the Eurovision network. The others were to carry message traffic of various kinds. Since then OTS has proved its worth for TV OB feeds and pan-European Cable services, and it is likely that even before the spare capacity on ECS-2 becomes available (not before the second half of 1983) we shall see a considerable amount of TV on the ECS system. Already a Dutch company, Euro-TV, is planning a 24-hour per day English language service, with Dutch subtitles, to be funded by subscription. Alternative language subtitling will be available via Teletext. Euro-TV has announced its willingness to accept private TVRO subscriptions from those not served by cable. A two-tier service is planned, with scrambling of premium programs.

ECS-1 primary power constraints permit simultaneous operation of nine of the twelve transponders during sunlit conditions, falling to five at eclipse. TV carriers will probably be offset above and below transponder center, to increase cross-polar isolation, but dual half-transponder TV is not envisaged. Cable TV feeds will be in the main on Spot West (Fig. 74), initially on transponders 6, 12, 4 and 10 (6X, 6Y, 4X, 4Y), close to the DBS band-edge (11.7 GHz).

FIRST GENERATION EUROPEAN DBS

OTS, ECS etc. are fixed service satellites, operating in the 10.95 to 11.70 GHz ("11 GHz") downlink FSS band. They are comparable with the birds that are to be used in North America (ANIK C for instance) for "interim" DBS, in the 11.7 to 12.2 GHz American FSS band. TWTAs are in the 20-watt class and nominal beam-edge EIRP levels are 47 dBW or less, requiring a receive terminal of 1.2 meters or larger. And the satellites are medium weight, in the region of 600 kg on-orbit mass, capable of being lofted by the Delta vehicle.

But for true DBS service, that is to meet the specifications laid down in the WARC-BS plan of 1979, the space segment for most countries requires a much higher power level. A **heavy-class** satellite (up to 2500 kg in orbit) is required, demanding a Shuttle or Ariane-3 launch, now that the Atlas-Centaur and Titan vehicles are obsolete for commercial flights. The DBS requires an RF power of 50 to 450 watts (dependent on size of service area) in each of five channels, to a spot beam of some 65 dBW EIRP. Individual home reception is then possible with terminals of 40 to 90 cm aperture, with relatively unsophisticated RF performance. The European DBS downlink band is 11.7 - 12.5 GHz.

WARC-BS

The WARC-BS criteria were based on the requirement for good reception with a 90 cm antenna for 99% of the worst month, using the receiver technology current in 1977. Receiver sensitivity (G/T) of ±6 dB/K was assumed, demanding a minimum power flux density of -103 dBW/m^2 within the service area as defined. With a 90 cm antenna the G/T performance can be had with a system noise temperature of 1800°K. But 3 dB noise figure LNCs are now available, giving a system noise temperature of only some 330°K - over 7 dB improvement.

The space segment is already defined, so the extra 7 dB (or maybe nearer 10 on boresight) is available to the TVRO. The antenna could be reduced to **40 cm**, or the service area could be effectively redefined, **7 dB further out**. Look what this means in terms of the accompanying footprints. Then think what a 3-meter antenna could do, 10 dB up again. It means that, co-channel interference permitting, most European DBS channels will be receivable virtually **anywhere in Europe** with only a 3-meter, 330°K system, well within the reach of community or Cable TV.

The satellites are not with us yet, but they are only three or four years away. First to set the DBS wheels in motion were the French and the West Germans, in the kind of collaboration that brought us SYMPHONIE. The two countries agreed to pool resources in technology, and to provide mutual backup in the event of satellite failure. Spacecraft development and integration programs proceeded independently.

TV-SAT

At present Germany is expected to be up first with the preoperational bird TV-SAT A3, perhaps as early as May 1985 but subject to possible delays (Fig. 75). A3 will be equipped for all five channels allocated to Germany at WARC-77 (see Fig. 5) but will in fact operate only three transponders simultaneously, two being held in reserve. EIRP will be a 65.5 dBW beam covering West Germany, with left-hand circular polarization from 19°W. RF power in each channel will be 260W from an AEG-Telefunken helix-type TWT. The spacecraft is designed for a 7 year

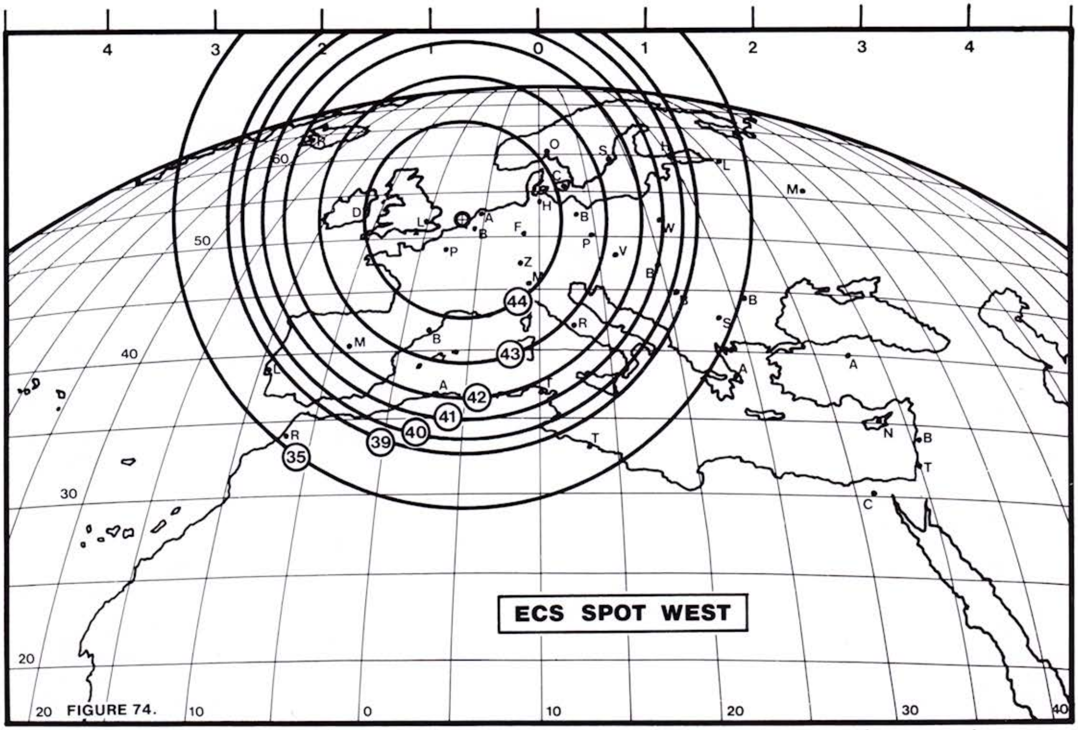


FIGURE 74.

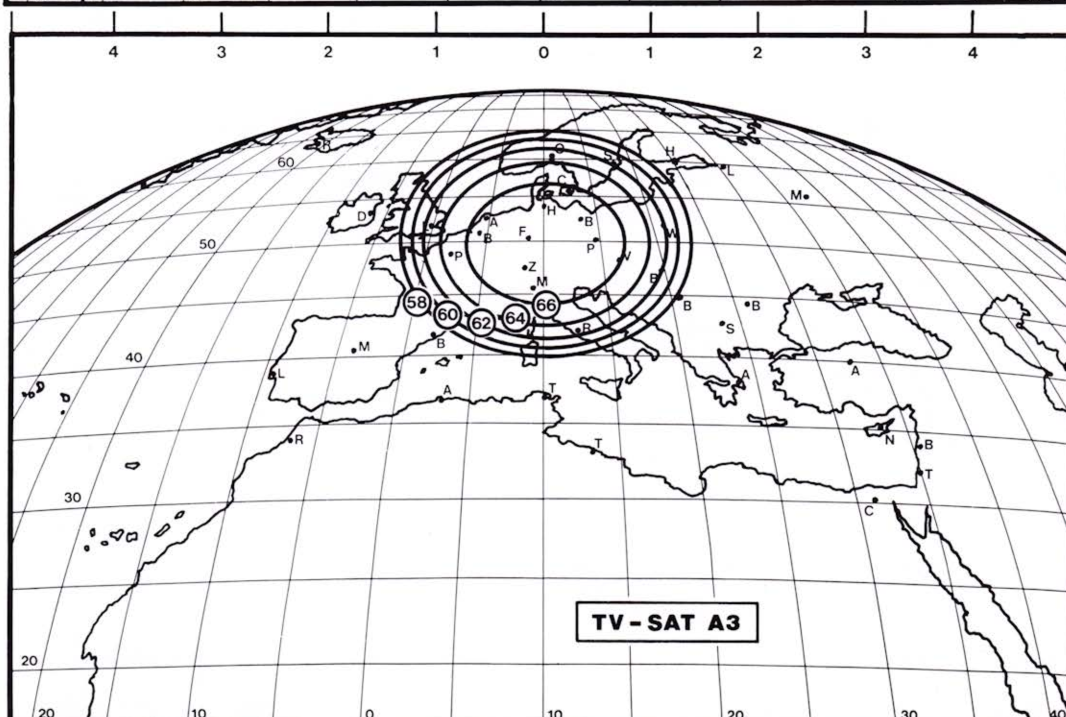


FIGURE 75. GERMAN DBS FOOTPRINT (12 GHz)

minimum life with antenna pointing, N/S and E/W stationkeeping all within ±0.1°. The operational satellite, TV-SAT A5, capable of supporting all five channels simultaneously, is expected two years after A3.

TDF-1

Hot on the heels of Germany comes France with TDF-1 (Fig. 76). Similar in concept, it will be equipped with three of the five French DBS channels (Fig. 5), each served by a combined pair of 220W TWTs to give the required 350W, delivering a PFD greater than -103 dBW/m^2 over mainland France and Corsica, and extending at this level into England, Belgium, Luxembourg, Germany, Switzerland, Austria, Italy and Spain. TDF-1 is due to go up in late 1985 or early 1986, and will also be stationed at 19°W.

L-SAT

Then there is L-SAT. The European Large Satellite Platform has become something of a way of life for the European Space Agency and its main contractor, British Aerospace. A multipurpose heavy satellite bus, L-SAT is capable of a variety of missions, including DBS, domestic or regional fixed service, global trunk, lease or mobile service and specialized commercial services including data communications using SS-TDMA. The first flight model, expected 1986 or 87 for the popular 19°W slot, will be equipped with two high power DBS channels, one as a pre-operational service with a fixed footprint covering Italy, the other as a test and demonstration DBS facility, steerable to serve almost any part of Europe. The Italian beam will comply with the Geneva Plan (Fig. 5), delivering a PFD in excess of -103 dBW/m^2 over Italy, with left-hand circular polarization in WARC channel 24. The steerable EBU beam will operate in channel 20 or 28 with a choice of polarizations.

L-SAT 1 will also fly a specialized service mission to test advanced business communications with a multibeam antenna covering Europe and an SS-TDMA package similar in operation to that on America's ADVANCED WESTAR. This is expected to downlink in the band 12.50-12.75 GHz. Also again on L-Sat 1 a multi-channel 20/30 GHz payload to test teleconferencing, SS-TDMA communications and other specialized applications thorugh small steerable spot beams. Propagation beacons on 12, 20 and 30 GHz are included, with European coverage.

BRITISH DBS

March 1982 saw the British Government committed to DBS for the UK in the second half of the decade. The BBC was awarded two channels on the first satellite, one a **premium** subscription (scrambled) service, the other a **free** "Window on the World" channel designed to show the best of current TV output. British Aerospace, GEC/-Marconi and British Telecom together formed United Satellite to provide the hardware. "Halley" has been suggested as the name for the DBS bird, after British astronomer Edmund Halley, whose comet should put in an appearance around the same time the satellite is due. The UK DBS orbital slot is at 31°W, and Great Britain has been allocated channels 4, 8, 12, 16 and 20 with right-hand circular polarization. 1986 is the provisional date, thought again schedules are expected to slip.

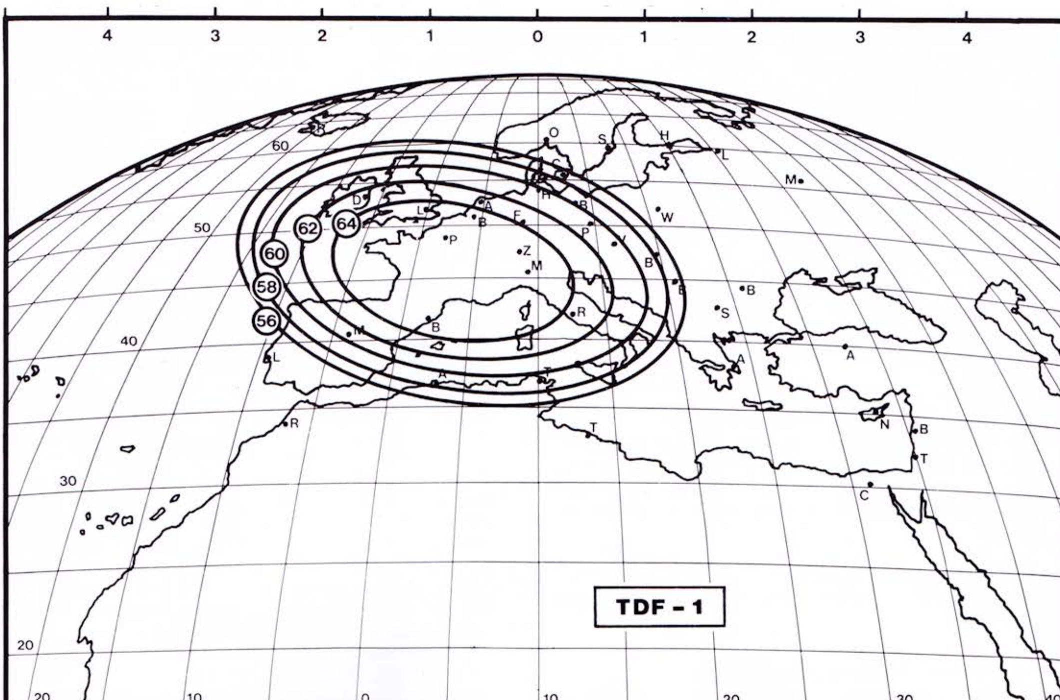


FIGURE 76. FRENCH DBS FOOTPRINT (12 GHz)

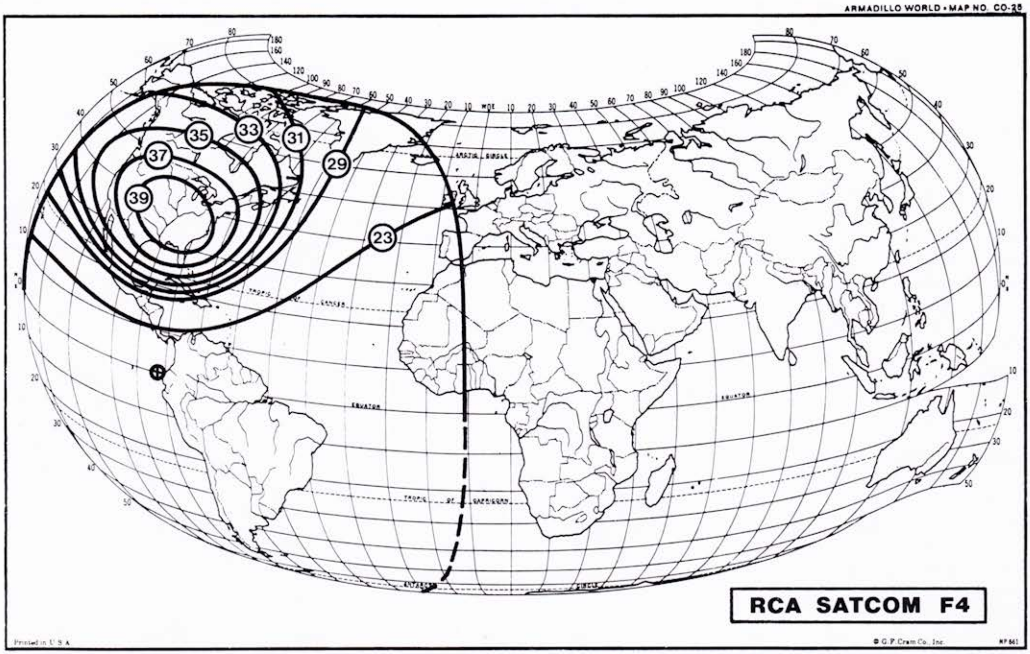


FIGURE 77. OFF-BORESIGHT EIRP projections for Satcom F4. The 23 dBW contour requires field tests for verification. Most favorable transponder set.

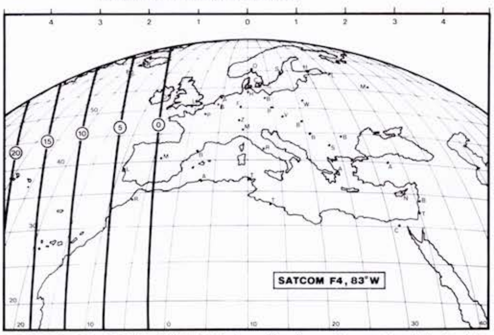


FIGURE 78. LOOK ANGLE (elevation) contours for F4 in the north-east Atlantic.

OTHERS

Otherwise Luxembourg (LUXSAT), Switzerland (TELSAT) and Sweden (TELE-X) are each reportedly working towards an early DBS appearance. Informed sources are doubtful of anything showing here before 1987 at the very earliest.

US DOMESTIC COMMUNICATIONS SATELLITES: 4 GHz RECEPTION POSSIBILITIES IN EUROPE

The demand worldwide for English-language satellite TV, and especailly American satellite TV, leads me to include a note on this subject. In general the US domestic birds are stationed too far West to be visible in Europe. Only recently, as the domestic arc fills up with C-Band satellites, have we started to see the easterly limits of that arc explored. The WESTAR slot at 79°W has seen some passing trade recently, but with nothing to attract the big dishes. Then in early 1982 RCA SATCOM F4 popped up at 83°W, with a nice selection of Cable feeds. One estimate of F4's coverage is shown in Fig. 77. (Another estimate puts one transponder set 2 dB stronger than this!) The visibility limit cuts through Ireland and Spain, enclosing Iceland and Portugal. The 23 dBW contour is of necessity a guess, and may be 3 dB or more in error in either direction. Antenna test range figures are notoriously unreliable so far off boresight, especially when they attempt to predict on-orbit performance. Unlike INTELSAT, a domestic satellite has one well-defined area to cover, and its designers don't worry too much about just where the -20 dB line falls.

Still it gives us a starting point for determining receivability, and is probably the best we'll get until you do a field survey and we publish the results. Fig. 78 plots elevation angle contours on the map of Europe, and shows us south-west Ireland at 2 degrees elevation, Reykjavik (Iceland) 3.5 degrees. Not good look angles, but with a cliff-top site and perhaps some local ground screening, who knows what could be done? Further south into the Canary Islands and western Africa, elevation increases to 10° or more, but at the same time footprint level declines - it is questionable whether a 6-meter system would yield good results, but certainly worth a try with umbrella

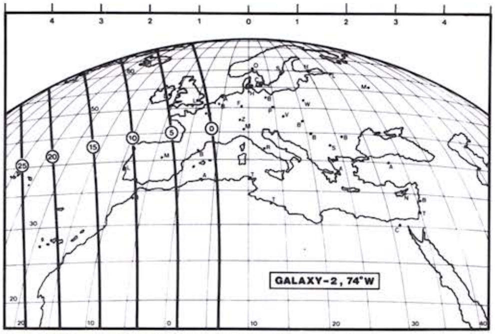


FIGURE 79. HUGHES GALAXY-2 will appear low over Europe's western horizon.

antenna and spectrum analyzer.

Moving ahead to September 1983 when Hughes GALAXY-2 is due up, to locate at 74°W. At the time of writing it is not projected as a "Cable bird" but it may carry some full-time TV. Footprint projections are not available so I cannot comment on EIRP levels, but the look angle contours are as shown in Fig. 79. Now the countries of south-west England have a fair sight (in our terms) at 5 degrees, so we must allow the possiblity of reception.

Then in late 1984 comes SPC's Spacenet-2 at 70°W. A problem here is that the higher these birds get above a European horizon, the more they have to look back westwards towards the USA, so what we gain on look angle we lose on EIRP level. The Spacenet satellites will have a shaped beam, optimized for CONUS, Alaska and Hawaii coverage from the SPC primary location of 119°W. At 70°W the "best fit" pointing of the antenna results in maximum EIRP being delivered to a spot in the Atlantic near Bermuda (Fig. 80). This excess of eastern footprint power could just possibly be to Europe's advantage, with maybe 20 dBW towards the UK, at an elevation angle of 5 degrees (Fig. 81). Just who will invest in a 10-meter rig could be a more interesting question than what he'll find with it, come 1984.

EPILOG

To list all of my sources and references would take up too much space, but I must thank the following who have offered encouragement, suggestions or information:

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Also grateful thanks to ADM, who supplied a 6-meter antenna which I hoped to use for observations, but have been unable to site in time for publication.

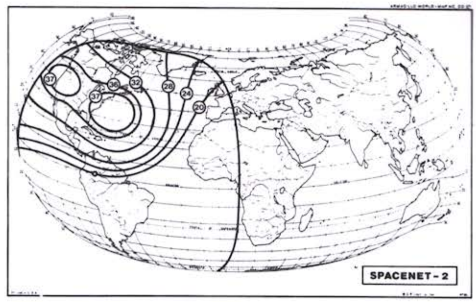

FIGURE 80. BEST FIT for SPC's shaped beam over USA from their secondary orbital slot may put "big dish" EIRP values into Western Europe.

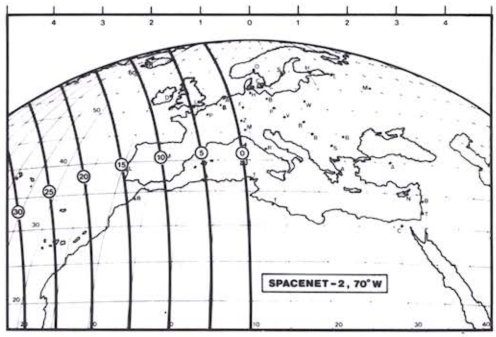

FIGURE 81. Usable elevation angles for SPACENET-2 will be encountered in Spain and Portugal and western parts of France and the United Kingdom. Iceland looks good for service.


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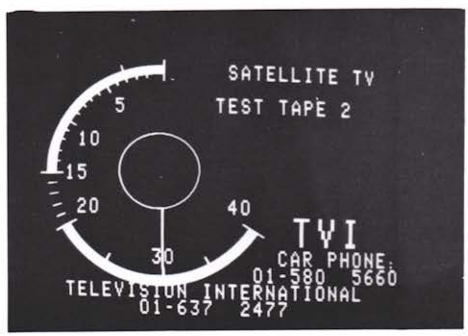
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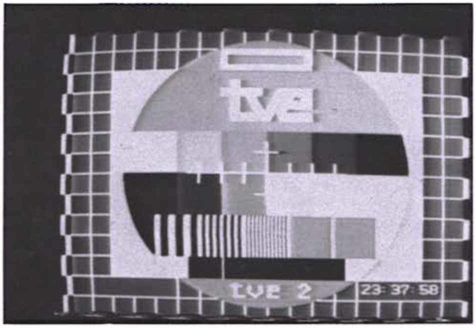
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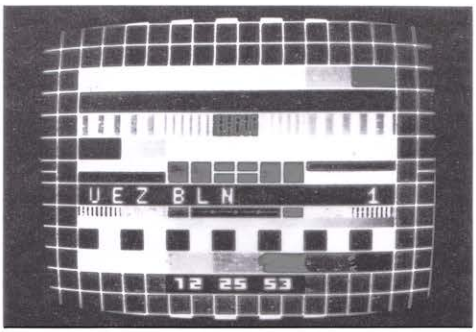
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