COMMUNICATION SATELLITE AND CABLE TV

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Of approximately 3000 cable TV systems, approximately 2/3 have 1000 or fewer subscribers. Many of these have looked forward to taking advantage of distributed cost of high quality programming by using the wide area broadcast capability of communication satellites in conjunction with low cost receive only stations and redistribution networks. Regulatory requirements, state of art hardware, spectrum availability, and in-place and planned space segments seem to forestall this hope. This paper explores the more significant system and economic considerations affecting the use of the space segment as it relates to satellite video and the associated redistribution networks.

Satellite communication systems became a reality in the last few years, when synchronous satellite technology became perfected. The most known and currently operational are ATS-6, INTELSAT's, ANIK, SATCOM and Western Union's WESTAR I and II; others are soon to follow.

In general all these geostationary satellites are capable of handling voice and data telephony, digital data and, primarily of interest to this audience, video and program material.

The quality of transmission is superior to that achieved by terrestrial systems. The overall reliability is at 99.95% (i.e., 43.2 seconds non-availability) and in practice achieves 100% on a short term (24 hour) basis.

In view of the above, communication satellites suddenly became not only the most desired means for point-to-point transmission of intelligence but also for simultaneous wide area Television and Broadcast program distribution.

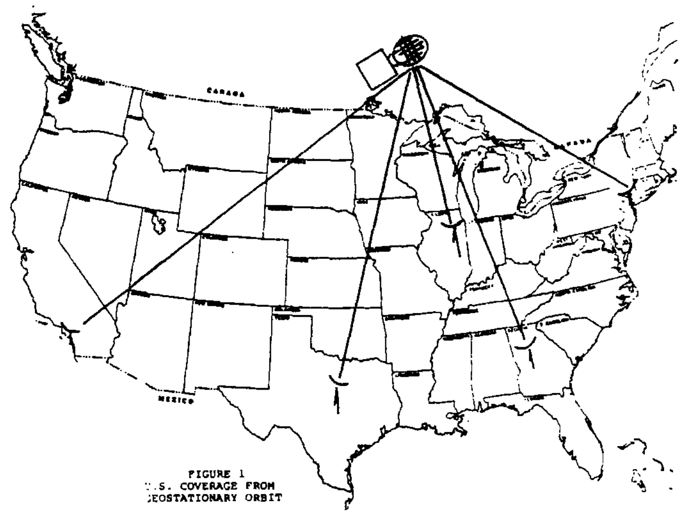


FIGURE 1
U.S. COVERAGE FROM GEOSTATIONARY ORBIT

This feature suggests that a number of suitable ground stations can be built for local rebroadcast purposes and, using satellite characteristic performance parameters, can be sized for a maximized economy in an envisioned application.

Presently the transmission is at 4/6 GHz (C-Band) and the trend is to shift to 12/14 GHz (Ku-Band) for the next, advanced technology, generation of communication satellites of 1980's.

This paper presents the technical background and establishes the rationale for this trend.

As a starting point one must be intimately familiar with parameters such as effective isotropically radiated power (EIRP), transmission frequency, location in orbit, polarization of the beam and useful bandwidth per transponder.

An overview of this type information is shown in Table I.

TABLE I

ITEM	INTELSAT IV	ANIK	SATCOM	ATS-6	WESTAR I & II
Launch Data	1969	1972	1975	1974	1974
No. of X-ponders	12	12	24	3	12
TWT Output W	5	5	4	10	5
X-ponder BW, MHz	36	34	34	30	36
Uplink Freq. GHz nom.	6	6	6	6	6
Downlink Freq. GHz	4	4	4	4	4
Avg. EIRP dBw	36	36	32	28	34
Design Life, yrs	7	10	8	6	10

As if was mentioned in the outset, the EIRP is one of the most important parameters for ground system planning and design. With this information the effective received power can be calculated and the balance of the receiving system designed. Typically this information is provided in a form of a footprint map.

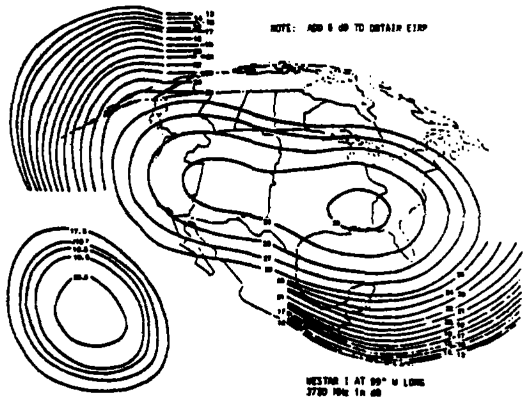
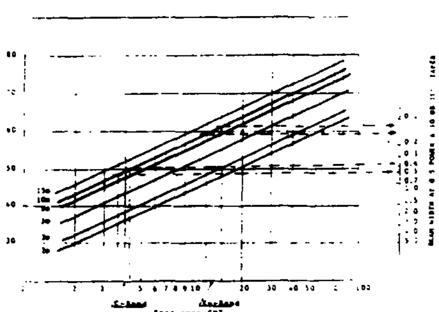


FIGURE 2
ANTENNA GAIN CONTOUR COVERAGE

Using the EIRP and frequency data the received signal power can be calculated. At the WESTAR receive frequency from the synchronous altitude, or 22,300 miles, the free space attenuation is in the order of 200 dB which relates to a ratio of 10^{20}. The handling of such a weak signal requires very careful consideration of the receiving antenna size and the quality of the receiving electronics, specifically that of the preamplifier.

The receiving antenna, if it is relatively large, can provide substantial gain to the signal strength prior to any kind of electronic amplification as depicted with curves in Figure 3.

FIGURE 3
THEORETICAL ANTENNA GAIN
55% EFFICIENCY



Another effect of operating frequency and antenna diameter is pointing beamwidth. This phenomenon is important for reception of the desired satellite from a group that is operating on the same frequency.

The gain obtainable from an antenna is a function of the operating frequency and diameter. The gain increases with an increase of the operating frequency and antenna diameter. At the same time the beam becomes progressively finer, thus improving discrimination between slosely spaced satellites operating on the same frequency but with different programs.

For maximized utilization of a transmit/receive spectrum that is the same for all satellites, it becomes necessary to place angular beam limits on both the satellite and ground station antennas which ultimately tends to drive the cost of the ground segment upward.

In addition to the two properties mentioned (gain and pointing beamwidth), reception of interferring ground based/generated signals is reduced with an increase of antenna diameter. This fact is of paramount importance in frequency coordination tradeoffs and is the reason for a general reluctance on the part of FCC to agree on antenna diameters less than 10 meters operating in the present 4-6 GHz band (C-Band).

The antenna for reception and transmission discussed above is a parabolic dish. Other antenna types are also available. One type that offers some advantages is a horn, shown in Figure 4.

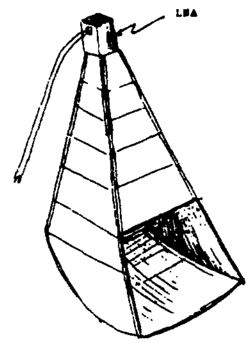


FIGURE 4
INVERTED HORN ANTENNA

The gain of a horn antenna is slightly higher than for a parabolic type of comparable inlet/acquisition area. This advantage can be as high as 6 dB. An improvement in terms of pointing accuracy, i.e. beam size and sidelobe reduction is also achieved. However, this antenna may not be practical for large aperture requirements. This type of an antenna is normally used upside down, as shown in the figure, or on roof-top installations.

Another factor in system design considerations is the noise level picked up by the antenna and contributed by the input stages of the receiving electronics, specifically preamplifiers. The noise levels are additive and determine the total system noise figure.

High gain antennas have an almost negligible amount of noise, i.e., about 0.6 dB. Input amplifiers, however, can be big offenders depending upon the type and quality used. The quality of a preamplifier is usually governed by the total permissible cost of the system in which it is used and the required gain-temperature ratio, and thus is subject to a cost tradeoff between antenna size and preamplifier noise figure.

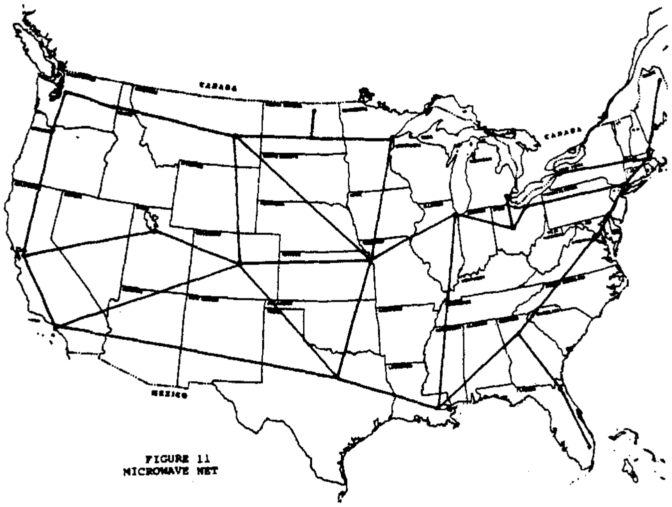


FIGURE 11
MICROWAVE NET

The reliability of such a system is good but is achieved only at a great expense in equipment redundancies, around-the-clock manning of T/R stations and other similar expedients. Due to these facts, operating costs are high.

This largely antiquated approach, dating back to the onset of transcontinental telephone networks, will gradually be replaced by the dedicated common carrier and privately owned, ground stations. Ground stations will serve an immediate area around its location with short microwave links as shown in Figure 12.

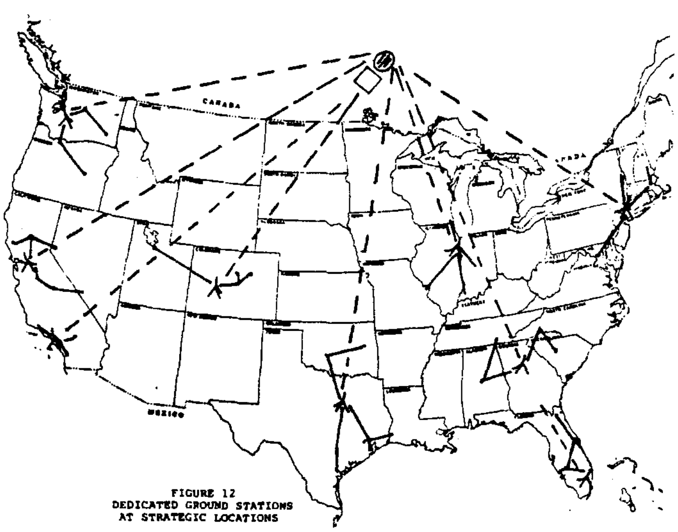


FIGURE 12
DEDICATED GROUND STATIONS
AT STRATEGIC LOCATIONS

Program material will be simultaneously available to the whole area of a country. A choice of program will be possible by dedicated multiple transponder assignments in the satellite and reception by frequency agile receivers in the ground station.

Transmit/Receive mobile ground stations in the 12/14 GHz freqency band will require no more than a collapsible installation on top of a van-truck with all the necessary electronics and support gear inside.

Both C-Band and Ku-Band space segments will be available in the 1980 decade. Some prognosticators predict the Ku-Band space segment will predominate in commercial transmission facilities in the late 1980's and the 1990's. However, the commitment to Ku-Band in terms of capital is not clear at this point in time. The demand for spectrum and orbital slots will be the pacing factor in this transition. Technology breakthroughs such as in fibre optics with significant cost reduction impact in terrestrial communication, could affect the transition to Ku-Band, but most likely to a minor degree in this century.

With reference to receive station costs in C-Band, for quantities exceeding 10, estimates tend to indicate a $60,000-$70,000 installed cost for non-redundant, one video channel, receive only station with an FCC compliant 8 meter antenna.

A C-Band receive only radio program station (10' antenna) for 2 channels of 8 KHz radio can probably be installed in quantities of 100 or more at costs of less than $10,000 per station, but with some risk of interference from ground and adjacent satellite transmissions.

C-Band transponder lease costs have moved downward from $3.5 million/year to under one million per year with unprotected service. Modulation equipment for transmitting two video channels in one transponder is becoming a reality.

With reference to Ku-Band, studies performed in the early 1970's indicate potential for video receive only stations that will cost under $1000 for quantities in the thousands.

Today, the cost requirement for receive only stations by the 2000 cable TV enterprises with 1000 or less subscribers each, may not be tolerable in the C-Band domain. However, with the acceptance of reduction of S/N from 55 dB to approximately 49 dB, with technology advances in front end electronics, favorable rulings by the FCC, and some implied risk with smaller antenna size, costs can come down to acceptable levels within a time frame well preceding development of adequate capacity and low cost hardware for the Ku-Band.

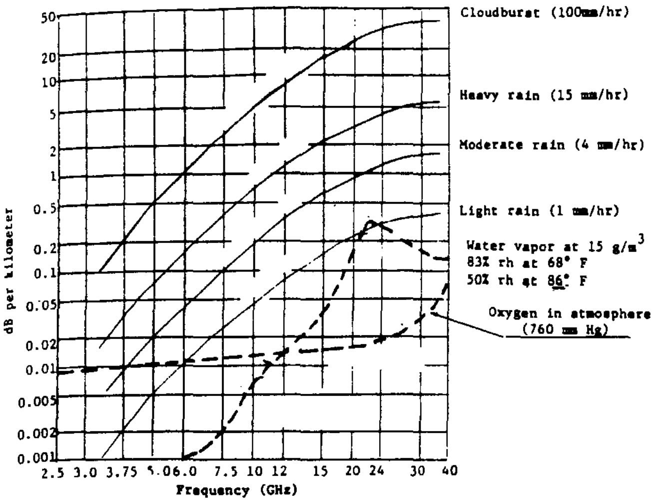


FIGURE 8
ESTIMATED ATMOSPHERIC ABSORPTION

Considering the ATS-6 frequency as 2.5 GHz, present day communication satellites at 5 GHz, as a median, and nominally 13 GHz for the future, one can see rather disturbing effects. Up to about 6 GHz the attenuation effects due to moisture and rain are negligible. In the Ku-Band planned for future communication satellites, this effect becomes an appreciable factor in overall system performance. This causes signal strength fluctuations as atmospheric conditions change.

The mechanism of this effect lies in the fact that the radio energy is absorbed and scattered by the raindrops. It becomes more pronounced as the wavelength approaches the size of the raindrops.

From this illustration, it appears that 15 GHz is the upper limit in selection of communications frequency over a long distance, such as it is found in deep space communications from synchronous satellites. However, advanced system designs for specialized applications beyond the oxygen molecular resonance frequency (approximately 23 GHz) are currently being planned. These systems will probably be out of cost range for commercial users in this century.

Summarizing technical and regulatory considerations, one can see that the general trend in satellite communications is toward the upper end of RF spectrum, i.e. 12/14 GHz, Ku-Band, and not toward S-Band. The summary of impact of reduced size antennas at C-Band and at Ku-Band is characterized in Figures 9 and 10.

C-BAND SMALL ANTENNA CONSIDERATIONS

- DECREASED DIRECTIVITY
- MORE SUSCEPTIBLE TO EXTERNAL NOISE
- LENGTHENED SUN OUTAGE TIME
- FCC COORDINATION DIFFICULT
- LIMITED UPLINK POWER
- UNINTENTIONAL INTERFERENCE WITH ADJACENT SATELLITES

HOWEVER

- WITH RISK TO USER - LOW COST RECEIVE ONLY STATIONS FEASIBLE
- TRANSMIT PORTABILITY REALIZABLE

Fig. 9

KU-BAND SMALL ANTENNA CONSIDERATIONS

- RECEIVE STATION CAN BE LOCATED AT USER SITE (ELIMINATED TERRESTRIAL FEED COSTS)
- MORE EXPENSIVE LOW NOISE AMPLIFIER
- SMALLER INTERFERRENCE DUE TO EXTERNAL NOISE SOURCES
- FCC COORDINATION FOR EQUIVALENT ANTENNA PERFORMANCE PARAMETERS IS LESS DIFFICULT THAN THAT IN C-BAND
- FCC DOES NOT CURRENTLY HAVE DOWNLINK POWER DENSITY LIMIT
- A 3 METER ANTENNA AT KU-BAND IS EQUIVALENT IN PERFORMANCE TO A 10 METER UNIT AT C-BAND
- PORTABILITY OF A KU-BAND ANTENNA AND ITS COST PERMIT BUILDING OF MOBILE GROUND STATIONS FOR SPOT COVERAGES

Fig. 10

The move to Ku-Band will result in significant cost reduction of antenna installation, support structure, an improved mobility (transportable, on the spot transmit/receive ground stations), elimination of terrestrial microwave feed systems, cheaper de-icing equipment or a possibility of housing in a bubble enclosure (radome), just to name a few.

Disadvantages can also be found: an increased cost of low noise preamplifiers, more susceptibility to antenna reflector inaccuracies, more critical system frequency stabilization and alignment and increased RF path attenuation (about 216 vs. 196 dB). However, in general, the advantages appear to outweigh the disadvantages. Also, the impact will diminish in view of the rapidly improving equipment design technology especially in the area of front end receive systems. Thus one can expect a significant system cost decrease by the start of the next decade, i.e. in the early 1980's.

An additional advantage in the use of Ku-Band is the lack of radiated power limitation toward the earth. This will partially counteract increased path attenuation and will minimize terrestrial antenna size increase.

System Economics

The subject of space communications would not be complete without a brief discussion of the system economics. A typical microwave net serving TV and Program distribution (Figure 11) constitutes a maze of point-to-point repeaters with individual drop-off points as required.

Typical preamplifier and antenna performance is shown in Figure 5 by type and as a function of operating frequency.

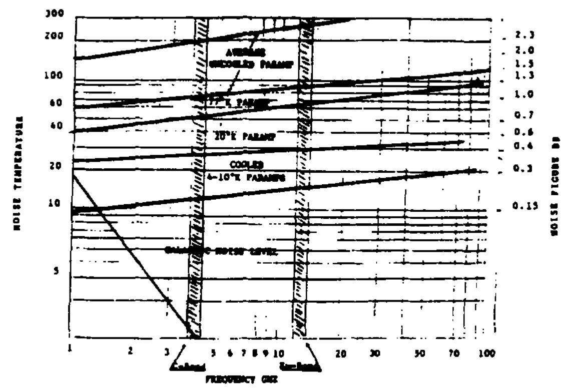


FIGURE 5
ANTENNA NOISE TEMPERATURE

The performance of both antenna and preamplifier is most conveniently characterized by the Gain/Temperature figure of merit.

The cost tradeoffs of antenna performance vs. preamplifier performance are shown in Figures 6 and 7.

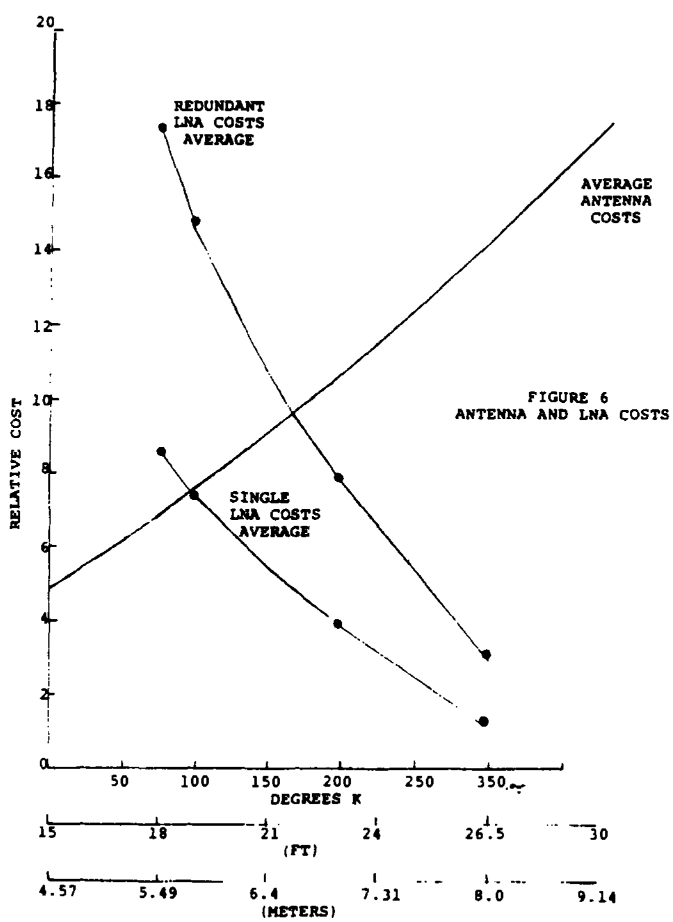


FIGURE 6
ANTENNA AND LNA COSTS

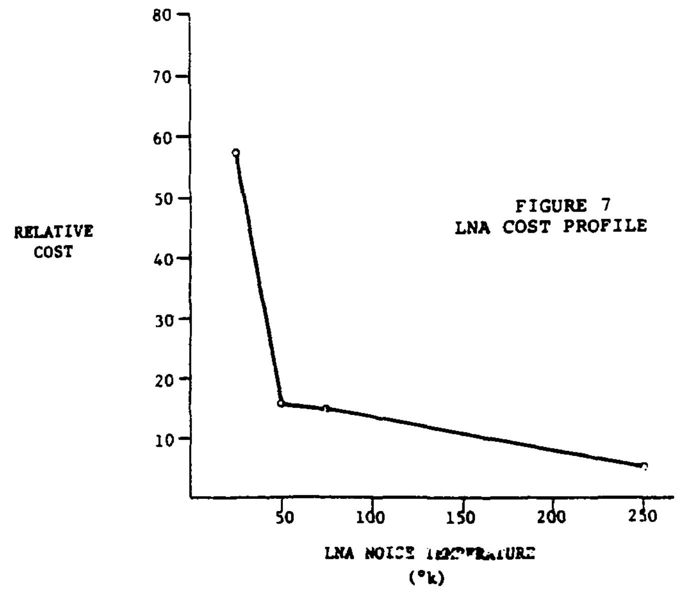


FIGURE 7
LNA COST PROFILE

It is evident from these figures, there is a crossover point which lies at the theoretical optimal point for a given system. These graphs were prepared for the 4-6 GHz band. Similar curves can be drawn for the future 12/14 GHz frequencies.

In general as frequency decreases the cost of antenna system with a given performance as a parameter will increase although not as drastically. The cost of preamplifiers, on the other hand, will drop significantly with frequency decrease but will rise sharply for frequency increase. From these considerations, another set of tradeoffs can be obtained and a conclusion drawn that ground stations for 2 GHz (i.e. S-Band) operations are less expensive than those of 5 GHz (i.e. C-Band). The opposite can also be said of ground stations for 12 GHz (i.e. Ku-Band). However, actual costs must be calculated through an exact system analysis. At times such an analysis can lead to very unexpected and at the first glance not obvious results, and it must be remembered that the performance of the satellite in a given frequency spectrum can move costs up or down by setting the required gain/noise parameter for the ground segment. This in turn specifies carrier to system noise ratio which further results in the signal to noise ratio in the video. There is room for compromise in that the EIA 55 dB S/N versus 45 dB can hardly be discerned in mass-produced home TV receivers.

The selection of satellite operating frequency was approached from the point of view of equipment costs. But another factor that enters into overall consideration is the increased attenuation of transmitted signal with an increase in transmission frequency. This effect is illustrated in Figure 8.