KU-BAND DISTRIBUTION OF TELEVISION PROGRAMMING FOR THE CABLE INDUSTRY

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INTRODUCTION

Ku-band for satellite delivery of television programming has become accepted worldwide. Abroad, European and Japanese satellite systems are based on the Ku-band frequency to take advantage of (1), higher power signals, which result in a less costly ground segment, and (2), relative freedom from RFI, which facilitates antenna siting.

In the United States, Ku-band has been selected for network television program distribution and for the establishment of nationwide satellite newsgathering services by several entities. It is also the preferred transmission technology for VSAT networking to establish private voice/data, transaction and video conferencing systems.

By 1992 67 percent of the satellites world wide will be operating at Ku-band. And of the 6 domestic U.S. launches planned between now and 1990, five are either Ku-band or hybrid.

The use of Ku-band for program distribution to CATV and SMATV systems is an evolutionary process, not a revolutionary step. Ku-band distribution allows affiliates to serve subscribers considered unreachable at C-band, eliminates the problems of C-band terrestrial interference encountered at some primary receive locations, provides a 2nd totally redundant signal distribution path thus protecting against program disruption and, over the next 3 years, allows an unprecedented increase in the efficient use of a satellite orbital slot and spectrum.

The success of Ku-band distribution requires the optimization of the satellite system including satellite performance, in orbit and ground protection to insure continued operation, and the frequency plan to ensure maximum utilization of the orbital resouce. On the ground careful planning and operation of the Ku-band receiving earth stations is needed to insure superior quality and reliable reception of the signal.

In July, 1986 subsidiaries of HBO and RCA formed a joint venture called Crimson Satellite Associates to build, acquire, and launch a Ku-band satellite called K3. Crimson also has the option to acquire and launch a second Ku-band satellite, called K4, and, subject to FCC approval, to co-locate it with K3. Launch of K3 is scheduled for Mid-1989.

An existing RCA Ku-band satellite, K1, serves to provide interim capacity until 1989 and allows the cable industry to build confidence in Ku-band distribution by providing a time to experiment and learn. Thereafter K1 will serve as an integral component in the satellite system protection plan.

WHY KU-BAND

The use of Ku-band for program distribution to CATV and SMATV systems is a natural step in our industry, as illustrated by examining future satellite systems.

A review of launch schedules reveals that the next generation of satellites are predominately Ku satellites.

Between now and 1992, 59 proposed communications satellites are authorized for launch worldwide. Of these, 52 will be Ku-band or Ku-hybrids, six will be C-band and one (Italy's) will operate at another frequency.

Between 1987 and 1990, Ariane has reservations or contracts to launch 32 communications satellites on 24 rockets. Of these 32 satellites, only one does not have a Ku-band payload. This inescapable fact merits emphasis: Every communications satellite launched between now and 1990 will be K-band, save one.

Ku-band has become the clear choice for future capacity for four important reasons:

1. Business Benefits to the Cable Industry:
   The benefits of Ku-band stem largely from its regulatory heritage. C-band satellites are secondary users of a shared-frequency assignment and consequently must not interfere with the terrestrial microwave links also using the spectrum. The interference is held to a minimum by operating C-band satellites at low power levels. Also, reception of C-band signals can be difficult or impossible because of interference from these same terrestrial microwave links.

   The Ku-band satellite service, on the other hand, is a primary user and does not need to protect any other radio service. Consequently, Ku satellites can be more powerful than those using C-band, permitting the use of smaller, less expensive equipment to receive the signal. This naturally provides business benefits to both programmers and cable affiliates, particularly as they look to serve areas not yet passed by cable plant. These business benefits include:

   ° The ability to situate a Ku earth station at an urban headend regardless of the presence of terrestrial microwave signals, which will facilitate construction as the major urban markets are cabled.

   ° In most cases, economical 1.8 meter Ku dishes for rural cluster cable systems not yet receiving satellite programming, thereby providing new services to homes heretofore unreached by programmers.

   ° Ku earth stations costing approximately $1300 can be used by operators to reach unpassed multi-family units (SMATV) prior to an urban cable build or in lieu of long cable runs to reach a rural pocket such as a trailer park or apartment complex.

2. Superior Protection Against Failure:
   Ku-band offers the opportunity to create a superior level of protection from catastrophe that is cost-effective, flexible, and adaptable to the evolving business environment. The objective is to maintain the business with minimal disruption to program continuity or the installed receiving system.

   Protection at Ku-band makes possible a protection configuration ensuring minimum disruption of service by eliminating the need to repoint earth stations at a new satellite or disperse programming across several satellites in the event of catastropic failure.

   Unlike any protection plan at C-band, Ku-band protection is achieved by on-board redundancy, an in-orbit spare satellite and a ground spare satellite. The growing base of Ku satellites means the cost of protection is reduced to each user while the number of C-band systems decrease, the cost of protection will be shared by fewer users, and thus cost to each user will increase.

3. Technical Evolution:
   The early Ku-band satellites were primarily designed for the transmission of high volume voice and data traffic from point A to point B using relatively large antennas. Ku satellites being constructed today and in the future will be

more suited to the predominant uses of satellite capacity -- video and point-to-multipoint small dish data transmission.

Ku-band satellite systems have been operational since 1980. The technology and performance characteristics have been studied and well-defined. The past 7 years of experience allows this new generation of Ku-band satellite to overcome many of the problems experienced in the past.

The early problems of degraded performance due to rain attentuation exhibited in the first generation Ku satellites have been overcome through the development of more powerful satellites capable of providing increased signal margin. Using the antenna sizes our industry employs, rain no longer degrades service for any significant time.

4. Channel Capacity:
Only 24 channels of video programming can be transmitted from each C-band orbital location. Therefore, headends are now "antenna farms" with an ever-increasing number of dishes looking at a variety of C-band satellites. The proposed channelization plan of the Crimson Satellite Associates Ku-band satellite system would allow each TVRO to receive a total of 32 program channels from a single orbital location.

CHARACTERISTICS OF THE K3 and K4 SATELLITES

The present FCC rules governing Ku-band satellites operating in the FSS band allow more flexibility in satellite design: i.e. higher power densities are permitted (compared with C-band) since interference with terrestrial networks is not a problem.

The design of the K3 and K4 satellites incorporate many advanced features that will enable the high performance requirements of the CATV and SMATV industry to be met across the country.

The Ku-band satellite system operates in the 14.0 to 14.5 GHz band on the uplink and in the 11.7 to 12.2 GHz band on the downlink. Each satellite includes sixteen transponders with 47 watt TWTAs (60 watts with FCC approval). Eight of the transponders will be horizontally polarized and eight will be vertically polarized. For high reliability, these sixteen transponders are protected by a total of six spare TWTAs on board the satellite.

The transponders will be fully protected against eclipse outage. This insures full operation and power for 24 hours a day, 365 days a year for the 10 year design life of the satellite.

The high power available from the TWTAs on board the satellite will be directed to the earth in one of three modes that are reconfigurable on orbit by ground command. These modes will allow any individual transponder to be configured as a CONUS beam or an East beam or a West beam. This allows the entire transponder power to be concentrated in the areas of the country where the signal is desired. Selectable coverage ensures that each transponder has flexibility for the user and can readily accomodate varying traffic usage patterns.

An EIRP pattern showing the minimum EIRP valves for 60 watt transponders expected for each of the transponder modes is shown in Figures 1, 2, and 3. The East beam provides coverage to the Eastern and Central time zones while the West beam covers the Pacific and Mountain time zones. The CONUS mode covers the 48 contigious states. Hawaii is covered in the West beam and CONUS modes. Two video signals per transponder can be accommodated, allowing up to 32 television channels to be distributed by one satellite.

Another innovative feature of this satellite is the on board dynamic limiter amplifiers (DLA). When the DLA is operating in the limiter mode, the transponder output is maintained at full downlink power even when the uplink signal fades. This insures that the overall video signal to noise ratio will be affected minimally by uplink fades and will obviate the necessity for expensive uplink power control at the transmit earth station. The inclusion of the DLA on board the satellite greatly enhances overall link robustness and provides a superior video signal in the event of propagation effects on the uplink.

The planned launch of K3 is in Mid-1989. An additional satellite (K4) can be launched at a later time and co-located with K3 (subject to FCC approval). The two satellites (each with sixteen active transponders) would then provide a total of 32 channels at a single orbital location. The satellite design is such that each of these 32 channels utilizes the full power of its own transponder. This is accomplished primarily by narrowing the bandwidth of each transponder from its nominal 54 MHz to a nominal 27 MHz upon ground command. This frequency plan, which is depicted in Figure 4 accomplishes an extraordinarily efficient utilization of the orbital location.

The satellite system design has been optimized for the transmission of television programs. The high power TWT's (operating at Ku-band) provide increased margin against propagation effects thereby permitting a substantial reduction in ground segment costs as well as a substantial increase in the number of locations where an earth station can be placed. The innovative frequency plan, employing transponders with switchable bandwidths, permits a single orbital location to provide 32 full power television signals into a single relatively inexpensive receive antenna. This ability to reconfigure each transponder individually and transmit the full transponder power in either full CONUS, Eastern or Western modes, the protection against the effects of uplink rain fade afforded by the DLA, the six spare TWT's and other on board satellite equipment redundancy, the use of switchable attentuators on the uplink to accommodate a variety of earth station transmit power capabilities and a satellite protection plan (described below) that calls for spare satellites (in-orbit and on the ground) to protect against the unlikely event of a catastropic satellite failure are all additional features of the satellite and satellite system that were designed to meet the needs of the CATV and SMATV industry.

K3/K4 PROTECTION PLAN

An earlier section (Why Ku-band) referred to the superior protection from catastrophe offered by a well designed Ku-band satellite system. The proposed Kl, K3, K4 system discussed here will provide a level of protection unheard of in other satellite systems.

Satellite-protection requirements have grown along with our industry's revenue stream. In the early days of satellite distribution, protection involved relocating programming to other satellites in the event of failure. Later satellites enhanced reliability by incorporating on-board spare parts.

Today, our industry uses dishes at more than 25,000 commercial locations to receive satellite programming. The protection scheme for the 1990s must provide programmers with the ability to stay in business in case of catastrophic failure without repointing thousands of dishes overnight.

Components of a sound, cost effective protection system include (1) on-board protection (spare components); (2) in-orbit restoration capability where the satellites move, not the dishes; (3) ground spares. Such protection will be achieved with the Kl, K3, K4 satellite system.

Once K3 is operational, the Kl satellite will serve as an in-orbit spare, which can be rapidly relocated to the K3 position in the event of a total K3 failure. Consequently, service restoration occurs in space, obviating the need to repoint thousands of dishes.

Furthermore, sometime after K3 is operational, K4 can be co-located with K3 (subject to FCC approval), operating 32 transponders from the same orbital location, achieving an even higher level of protection. In order to co-locate K3 and K4, the satellites need to be clones. Alone, each satellite has the highest ratio of redundant spare-parts to active-parts of any satellite placed in-orbit to date. When K3 and K4 are co-located, the sum of their spare TWT amplifiers, receivers, etc., is virtually the equivalent of a spare satellite. If a problem occurs, on-board spare equipment can be called upon to replace practically 50% of the critical parts on either satellite.

If it becomes necessary to replace any of the orbiting satellites, a compatible ground-spare satellite, constructed along with the active satellite, will be readied for launch.

The costs of the in-orbit and ground-spare capability are shared among all the users of the entire RCA satellite system, thereby minimizing costs to each.

KU-BAND CHARACTERISTICS AND SYSTEMS CONSIDERATIONS

For a given power radiated from the satellite, the earth station size and receive noise temperature (G/T needed) is determined by the performance required (the video signal-to-noise ratio) and the availablity or the fraction of time this performance will be provided. The availability is a function of equipment availability and propagation effects. The major propagation effects on satellite links at Ku-band are due to rain. (The largely ignored effects of sun outage at C and Ku will be discussed later.) These effects lead to the attentuation of the signal propagated through the atmosphere and an increase in the receive system noise temperature due to the warm rain.

The total attentuation of the signal (expressed in dB) over the earth-space path is of the form

$$A = \alpha L \qquad (1)$$

Where α is the rain attenuation in dB/km and L is the effective path length through the rain.

The effective path length depends on the elevation angle of the receiving antenna and on the rain rate. For low rain rates, such as 5 to 10 mm/hr (light rainfall), L is the true path length through the rain, while for high rain rates such as over 40 mm/hr (heavy rainfall), the non-uniform nature of the rain storm requires an empirically determined correction factor to compute the effective path length.

The degradation of the received C/N is a result of the signal attentuation caused by the rain along the signal path and the increase in system noise temperature caused by the warm rain. This total signal degradation due to rain is called Rain Loss and is given by:

$$\text{Rain Loss} = A + 10\log\left[1 + \frac{290}{T_s}\left(1-10^{-.1A}\right)\right] \text{dB} \qquad (2)$$

where T_s is the clear sky system noise temperature (°K) and A is the signal attentuation (in dB) caused by the rain as calculated in Equation (1).

The rain regions of the world and the United States have been identified and characterized as shown in Figure 5.

For a given earth station site, the rain rate statistics appropriate to the rain region in which the site is located are used. The elevation angle to the satellite is determined and the rain attentuation and the Rain Loss are computed as in equations 1 and 2 above.

The carrier-to-noise ratio under rain conditions is related to the clear air carrier-to-noise ratio by the following:

$$C/N_{\text{rain}} = C/N_{\text{clear}} - \text{Rain Loss}$$

Figure 6 shows the rain loss for a number of cities for a system noise temperature of 290°K for the satellite located at 85° West Longitude.

The information contained in the figure is the margins needed to accomodate the atmospheric effects of signal fading and increase in the receive system noise temperature at various locations throughout the country. The margins needed have been combined with the EIRP values for K1 and K3 to obtain the video signal-to-noise ratio versus availability across the United States for a given antenna size.

These results have been plotted for K1 on the contours shown in Figures 7. The results for K3 (with 60 watt transponders) are plotted in Figures 8 and 9.

SIGNAL OUTAGE AT KU-BAND

Discussions of Ku-band delivery systems inevitably turn to the topic of rain outage or rain fades. The general perception is that Ku-band is plagued by significant rain outages (program distruptions) and that C-band is not. In fact, this is the most often used argument against using Ku-band frequencies for distribution to CATV and SMATV systems.

Most of the force of this argument has been eliminated by the design of the K3/K4 satellites and the inclusion of sun outage into overall availability or outage calculations for C and Ku-band systems.

Most of the experience with Ku-band rain outage was gained on first generation Ku-band satellite systems. These systems used 10 watt or 20 watt satellites and spread this relatively low power across all 48 states. Receiving systems, using first generation electronics, incorporated low noise amplifiers with noise figures of 3dB or larger (the smaller the noise figure, the better the performance). The result was very low rain loss margins resulting in the rapid onset of signal degradation under rain conditions.

The K3/K4 satellites are designed to improve the rain loss margin. Each satellite carries sixteen 47 watt transponders (60 watt transponders with FCC approval). The result is about 4-7 dB of improvement in margin over the 10 or 20 watt satellites when K3 or K4 are in full conus mode and about 6.5 - 10dB of improvement when K3 and K4 are in half conus mode. A typical receiving system today includes antennas with an efficiency of 65% or better, resulting in a higher antenna receive gain, and a LNB with a typical noise figure of 2.5 dB or better.

These improvements in satellite and TVRO performance have dramatically increased the amount of rain fade that the system can tolerate before signal degradation becomes a problem.

A factor almost always overlooked when discussing signal availability is sun outage. Sun outage occurs twice a year in the Fall and Spring for a total of 18 - 20 days. Sun outage occurs when a given receiving TVRO, the satellite and the sun line up. During these occasions, random noise from the sun, to varying amounts degrades the received video signal. Sun outages are a fact of life, affecting C and Ku-band systems to differing degrees.

Table 1 shows the number of minutes over a year the received video signal to noise will fall to 45dB or less for a 4.5 meter C-band TVRO receiving a signal from RCA Satcom F3R and 1.8 meter and a 3.1 meter Ku-band TVRO receiving a signal for RCA K1 in full conus mode. As defined for rain outage, a video S/N of 45 dB or less caused by sun degradation is considered an outage. Using K1 in CONUS mode is a worst case situation since K3 provides over 1.25 dB more margin in CONUS mode than K1 and an additional 2.5 dB of improvement over CONUS when operating in the East or West beam modes.

TABLE 1
MINUTES OUT OF THE YEAR THAT S/N FALLS TO 45 DB OR LESS DUE TO SUN OUTAGE ONLY

C-band (4.5 meter TVRO, RCA Satcom 3R)	138 minutes
Ku-band (1.8 meter TVRO, RCA K1 CONUS)	22 minutes
(3.1 meter TVRO, RCA K1 CONUS)	20 minutes

Table 1 clearly shows that the C-band TVRO experiences significantly more sun outage than the K-Band TVRO. The availability for this C-band system can be shown to be 99.97%. The availabilities shown in Figures 7, 8 and 9 for various Ku-band receiving systems demonstrate there is very little difference between C and Ku-band availability.

KU-BAND RECEIVING SYSTEM DESIGN

System Design

Given the inescapable benefits of Ku-band delivery, the optimized satellite operating characteristics and the unrivaled protection plan offered by the satellite system, close attention must be paid to the TVRO system to ensure that the installed ground segment does not become the weak link in the overall system.

Program distribution to CATV and

SMATV systems requires very careful system design, installation and operation to ensure continued high performance.

Crimson Satellite Associates have identified certain performance requirements to be achieved by TVROs utilized to receive the K1 and K3 distributed programs. See Table 2. The TVRO systems distributed to cable systems by HBO and RCA American Communications, Inc. ("RCA Americom") were selected to conform to these performance requirements.

TABLE 2

SIGNAL AVAILABILITY AND OUTAGE DEFINITION FOR RAIN LOSS ONLY

Signal availability CATV :
99.99% (goal)
Signal availability SMATV:
99.9%

Signal outage occurs when:
S/N_{Video} equals or falls below 45dB

Clear sky S/N_{Video} :
50 dB or better

Signal availability, as previously described, is the percentage of a year that the signal received by a CATV or SMATV TVRO exceeds the specified outage threshold level. From the above table, a CATV system should provide to the extent possible a video signal with a S/N greater than 45 dB 99.99% of the year and an SMATV system must perform to that extent 99.9% of the year. In other words, a CATV system should have an outage as defined in Table 2 of no more than 53 minutes out of the year and an SMATV system for no more than 530 minutes out of the year. Two very important points must be recognized and considered when evaluating the signal availability requirements in Table 2. First, the availablity here refers only to signal degradation caused by rain or atmospheric conditions. It does not include other system induced degradations such as sun outage. Secondly, the term outage as used in this analysis is misleading. For the purpose of conservative system design and to insure system margin, a signal outage is defined by Crimson Satellite Associates as a video signal exhibiting a S/N of less than 45 dB. A 45 dB video signal is still a very acceptable picture and provides plenty of margin from that point to where the picture is actually unusable. If a lower S/N is used as the outage criteria, system availability improves.

The selection of Ku-band TVROs distributed by HBO and RCA Americom was made as follows:

From the requirements of Table 2, the Rain Loss for multiple sites in each rain zone was calculated. This Rain Loss described the amount of margin between clear sky performance and the defined outage to be provided by the TVRO. Equation 3 and 4 were then used to calculate the required TVRO gain needed to provide that margin.

$$C/N = S/N_V - RTF \quad (3)$$

$$G_A = C/N - EIRP + Ls + Lp - 228.6 + 10\log Ts + \text{Rain Loss} + 10\log B \quad (4)$$

Where:

RTF = Receiver Transfer Function
G_A = Antenna Receive Gain
Ls = space Loss
Lp = Pointing Loss
Ts = System Noise Temperature
B = System Noise Bandwidth

Note that the required gain was calculated for the worst case operational conditions; K1 EIRP in full CONUS mode on the lowest powered transponder. Half CONUS mode operation will only improve availability. Also, K3 provides an increase in CONUS and half CONUS EIRP compared to K1, thus improving performance further.

If the calculated gain did not achieve at least a 50 dB Video S/N under clear sky conditions, the gain of the system was increased accordingly. Available TVRO components were then selected to build the required TVRO system.

Figures 7, 8, and 9 show the required antenna sizes for a given availability for K1 and K3.

The 22 minute sun outage discussed earlier reduces the availability shown by .0042%.

System Installation and Operations

Ku-band TVROs require slightly more

care with installation and operation than a C-band TVRO. While the special requirements are not onerous, they must be recognized if the systems are to perform at maximum capacity.

The wavelength of a Ku-band signal is about 1/3 that of a C-band signal. This means that the main beamwidth of a Ku-band antenna is about 1/3 the beamwidth of a C-band antenna of the same size. The reduced beamwidth imposes a requirement to aim the Ku-band antenna more accurately than a comparable C-band antenna and to hold the antenna as still as possible. Movement of a CATV or SMATV Ku-band antenna can cause a signal degradation of 2 or 3 dB. This amount of degradation is not critical under most operating conditions but it does reduce the system rain loss margin. Additionally the reduced wave lengths of Ku-band frequencies requires the antenna reflector surface smoothness to be held to a tight tolerance and the shape of the antenna be as close as possible to the required parabolic shape.

The installer of a Ku-band TVRO must take steps similar to the one he would take when installing a C-band TVRO to ensure the pad and all reflector mounting hardware is rigid and capable of holding the reflector as motionless as possible in expected wind conditions. Also, during reflector assembly, care must be taken not to distort the reflector surface by over torquing bolts or denting or bending the reflector.

Antenna pointing and polarization alignment of a Ku-band TVRO is similar to that of a C-band TVRO. However, because of the very high S/N of the video signal received under most conditions, the installer can be misled about the accuracy of his alignment efforts. A Ku-band TVRO, under most operating conditions, produces a video signal far superior to that produced by a comparable C-band system. In fact, the quality of the received picture is so good that even a 2 or 3 dB degradation in the received signal C/N due to antenna misalignment is not noticable by viewing the picture on a TV set. However, the result of antenna misalignment is to cause the system margin to be reduced. The reduced margin in turn causes the defined outage level to be reached quicker than predicted, thus reducing the signal availability.

It is recommended that the operator align his Ku-band TVRO using a field strength meter or if possible a spectrum analyzer instead of viewing the received picture quality on a TV set. Additionally, as with C-band TVROs, the antenna alignment should be peaked periodically when the satellite is in the center of the box.

CONCLUSION

This paper has attempted to familarize the reader with Ku-band satellite requirements, the advantages of Ku-band distribution and system operating considerations.

Ku-band provides: (1) the opportunity to operate a TVRO in an interference free environment thus opening up additional business opportunities; (2) unheard of protection against business disruption and ground segment disruption in the event of a satellite failure; (3) video signal performance superior to C-band for comparible antenna sizes; and (4) signal availability equivalent to C-band when both rain fade and sun outage effects are considered.

The C-band satellites used by the cable industry reach the end of their design lives by 1992. Therefore, 1987 is the year to focus on the transition to the next generation of satellites. A short term re-location to a satellite with 2 or 3 years additional life is not a solution. In fact, it puts the industry at a competitive disadvantage with the evolving technology and actually presents the risk that a launch opening will not be available when a successor satellite needs to be launched.

The satellites of the future will be state-of-the-art Ku-band. They will be capable of affecting both cable operators' and programmers' businesses and may be operated by companies with little or no investment in our business. The cable industry cannot afford to restrict itself to yesterday's technology. Today, with Ku-band technology, we have the opportunity to maintain a competitive technological edge - an opportunity that has come at a time that is a natural decision juncture for satellite capacity planning.

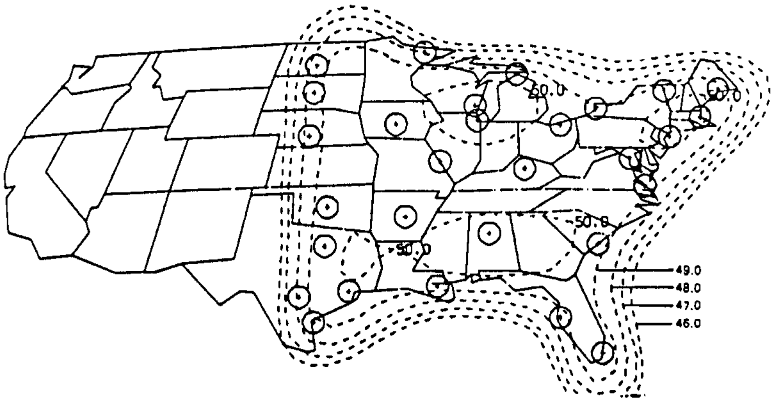


FIGURE 1*
EIRP CONTOURS (dBW) FOR EAST BEAM

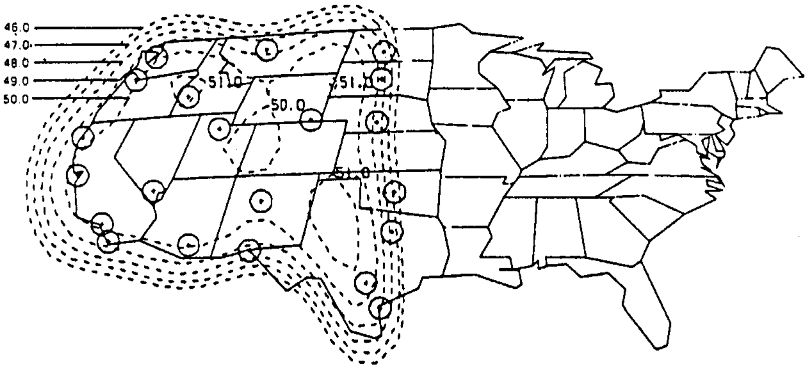


FIGURE 2*
EIRP CONTOURS (dBW) FOR WEST BEAM

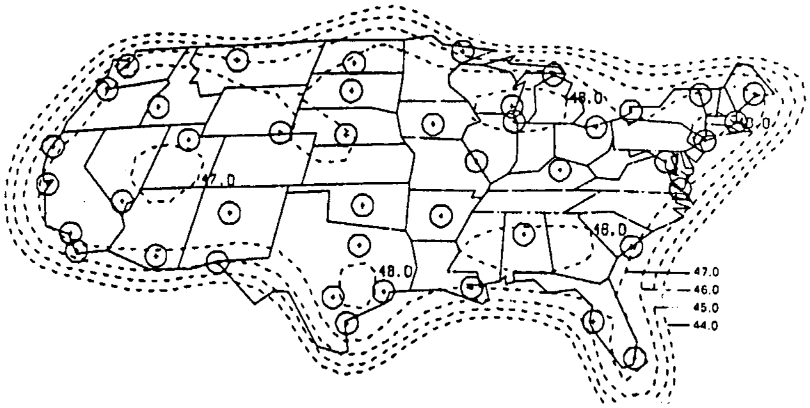
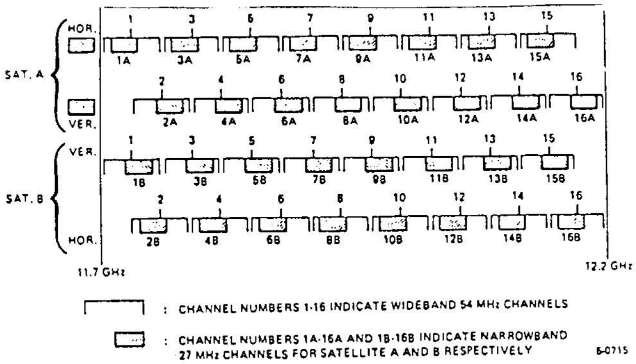
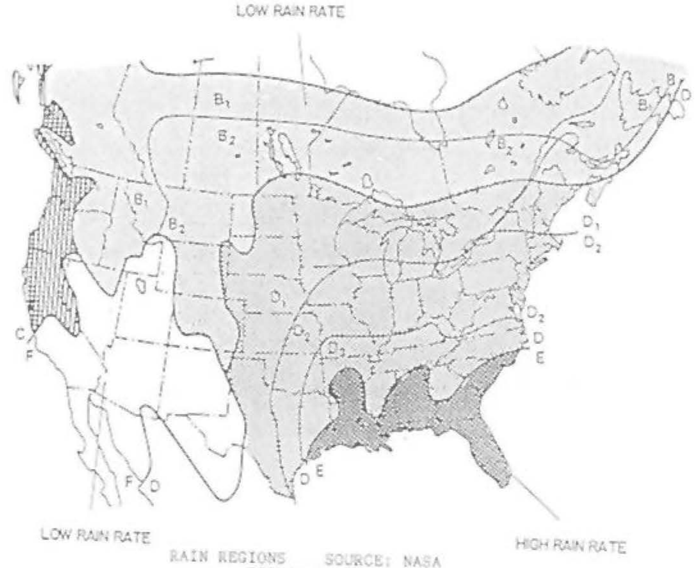


FIGURE 3*
EIRP CONTOURS FOR CONUS

*CONTOURS FOR 60 WATT TRANSPONDERS (PENDING FCC APPROVAL). 47 WATT TRANSPONDERS' CONTOURS ARE REDUCED BY ABOUT 1 dB FROM THOSE SHOWN.

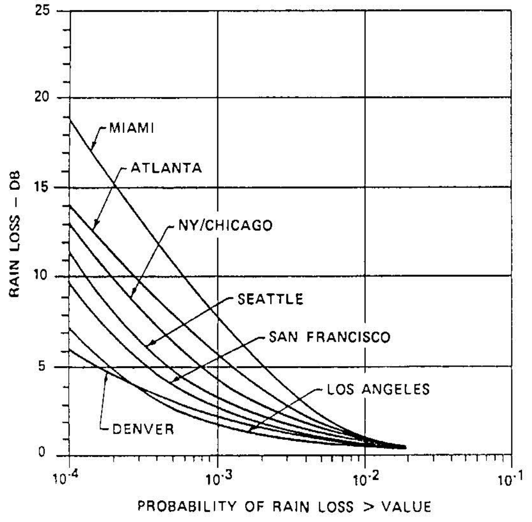


K3/K4 CHANNELIZATION PLAN
FIGURE 4



RAIN REGIONS SOURCE: NASA
FIGURE 5

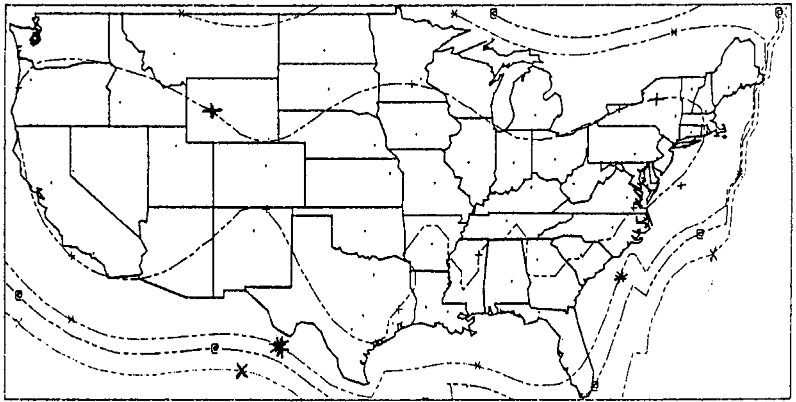
SATELLITE AT 85°W
RECEIVE SYSTEM TEMPERATURE – 290°K



RAIN LOSS AT VARIOUS CITIES
FIGURE 6

FIGURE 7

ANTENNA SIZES TO ACHIEVE 99.9% AVAILABILITY WITH K1 FULL CONUS

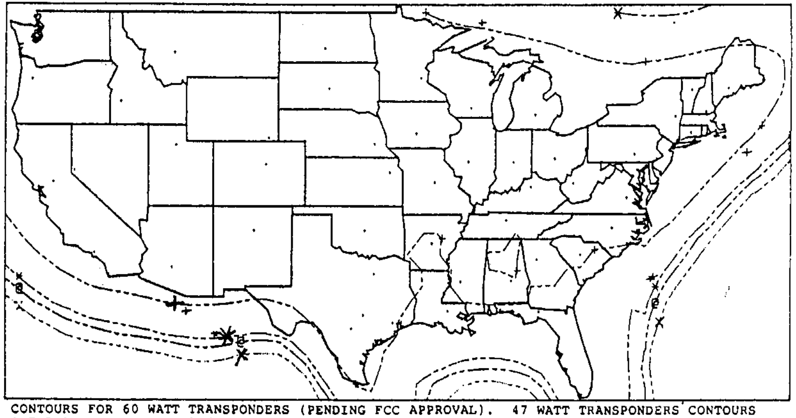


CONTOURS FOR 60 WATT TRANSPONDERS (PENDING FCC APPROVAL). 47 WATT TRANSPONDERS CONTOURS ARE REDUCED BY ABOUT 1 dB FROM THOSE SHOWN.

+ 1.8 METERS	@ 3.7 METERS
* 3.0 METERS	X 5.5 METERS

FIGURE 8

ANTENNA SIZES TO ACHIEVE 99.9% AVAILABILITY WITH K3 FULL CONUS

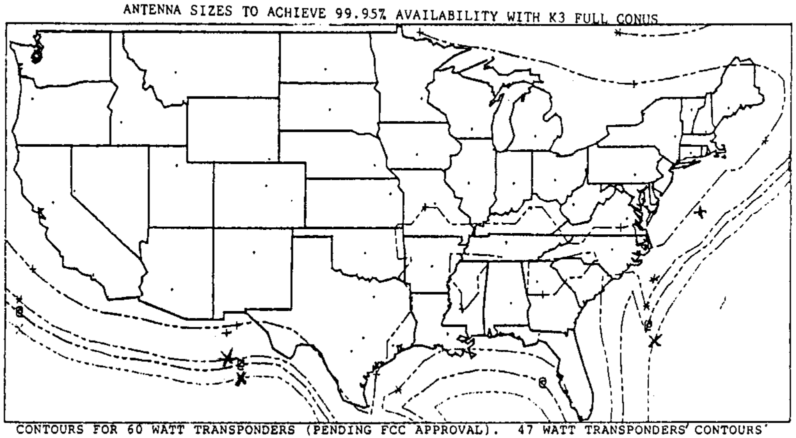


CONTOURS FOR 60 WATT TRANSPONDERS (PENDING FCC APPROVAL). 47 WATT TRANSPONDERS CONTOURS ARE REDUCED BY ABOUT 1 dB FROM THOSE SHOWN.

+ 1.8 METERS	@ 3.7 METERS
* 3.0 METERS	X 5.5 METERS

FIGURE 9

ANTENNA SIZES TO ACHIEVE 99.95% AVAILABILITY WITH K3 FULL CONUS



CONTOURS FOR 60 WATT TRANSPONDERS (PENDING FCC APPROVAL). 47 WATT TRANSPONDERS' CONTOURS' ARE REDUCED BY ABOUT 1 dB FROM THOSE SHOWN.

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