EARTH STATION DESIGN CONSIDERATIONS
FOR 2° C BAND SATELLITE SPACING

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INTRODUCTION

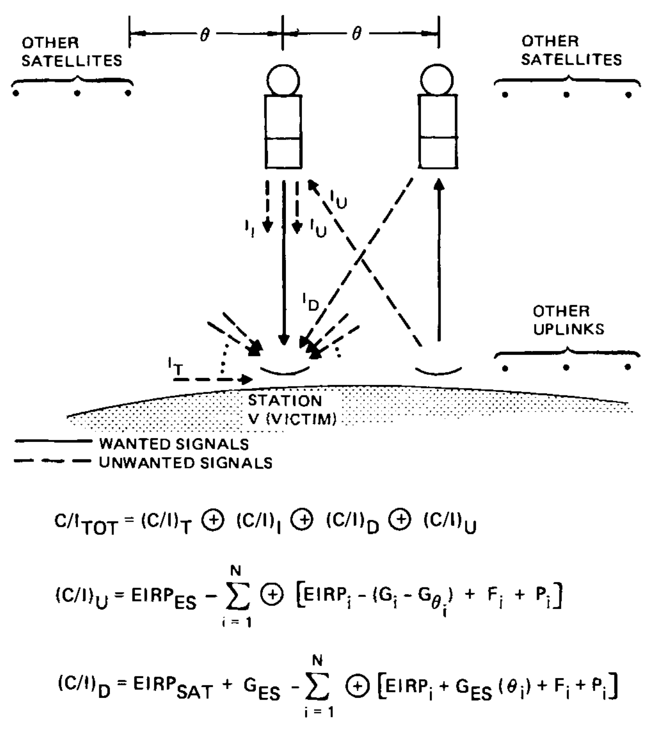
The Federal Communication Commission "Open Skies" policy, which allowed technically and financially qualified entities to launch and operate domestic satellite facilities, has been a great success. Benefits to virtually all elements of the telecommunications industry and ultimately to the public have been derived. The policy has certainly been a positive factor in the CATV industry, and perhaps a major technological catalyst in its development.

The geostationary orbital arc, that imaginary line 22,300 miles above the earth's equator, is a finite resource. It has been 2-1/2 years since the Commission made its last C-band authorization[1]. That round of authorizations established a constellation of C-band satellites with 4° spacing. Most of those satellites are currently in orbit, some will be launched this year, and the balance next year. The applications kept coming to the Commission, and in November 1981 a Notice of Inquiry and Proposed Rulemaking[2] was issued relating to the implementation of a 2° spacing plan for both C-band and Ku-band satellites. The rulemaking involved establishment of new technical standards for earth station antennas relating to the gain and cross polarization isolation in the close-in sidelobes. Comments were made by 37 entities. At last year's NCTA convention this author was moderator of a session on this subject and gave a detailed report on the comments received by the Commission. At the time this paper is written, the FCC has still not completed its deliberations in this docket. Regardless of the exact determination, CATV existing facilities will be adversely affected. The degree to which they will be affected and when this will take place is speculative, and any analysis ultimately involves a subjective evaluation of an acceptable level of interference.

This paper will outline the ground terminal receive only design considerations for 2° spacing of C-band satellites to permit antenna manufacturers to assess and respond to the changing marketplace. By the same token, operators should be aware that their facilities will probably need to be upgraded.

CARRIER TO INTERFERENCE RATIO

Consider the complex situation of the receiver of station V in Figure 1. It must contend with interference inside its passband from terrestrial sources and its own satellite's internal sources. It also is bombarded with interference from other satellites and from uplink stations transmitting to other satellites. The receiver's only asset to counter this interference is



$$C/I_{TOT} = (C/I)_T \oplus (C/I)_I \oplus (C/I)_D \oplus (C/I)_U$$

$$(C/I)_U = EIRP_{ES} - \sum_{i=1}^{N} \oplus \left[EIRP_i - (G_i - G_{\theta_i}) + F_i + P_i\right]$$

$$(C/I)_D = EIRP_{SAT} + G_{ES} - \sum_{i=1}^{N} \oplus \left[EIRP_i + G_{ES}(\theta_i) + F_i + P_i\right]$$

FIGURE 1. INTERFERENCE MODEL

its antenna off-axis discrimination characteristics. If antennas had no sidelobes, no problem would exist; it would be necessary only that satellites other than the desired one be spaced outside the main beam or, conversely, that the beam of the earth station antenna be narrower than the spacing between satellites. Of course, the earth station's antenna must have cross polarization isolation in the main beam because cross polarized signals are coming in from the desired satellite. We live in an imperfect world, however, in which antennas have sidelobes. It is sidelobe characteristics which will be discussed here.

Table 1 quantifies the interference situation. The values assumed for $(C/I)_T$ (terrestrial), $(C/I)_I$ (internal) and $(C/I)_U$ (uplink) are reasonable, assuming the station is properly protected from terrestrial sources and that suitable uplinks are accessing other satellites. In the $(C/I)_{TOT}$ column two figures are used. The first figure, 18dB, is generally accepted as adequate for CATV viewing. Some conservative members of the CATV industry, however, would like to design for higher values. The $(C/I)_D$ (downlink) column is the result of power addition and represents design criteria for the receiving antenna, based on each value of $(C/I)_{TOT}$.

TABLE 1

$(C/I)_{TOT}$ dB	$(C/I)_T$ dB	$(C/I)_I$ dB	$(C/I)_U$ dB	$(C/I)_D$ dB
18	25	26	27	19.9
20	25	26	27	23.6

A conservative approach would not depend on cross-polarization isolation from other satellites, because this factor is extremely weather dependent. Modest rainfall and uneven snow buildup on the antenna will destroy the off axis cross-polarization discrimination, thereby affecting the reliability of service. Any benefit to be derived from adjacent satellite cross-polarization should be regarded as margin in the overall system design.

Another important consideration is that the space constellation is not homogeneous, and it is not feasible to attempt to produce this condition by regulating EIRP. The earth station antenna design should take into account at least a 3 dB difference between the desired satellite EIRP and that of adjacent other satellites.

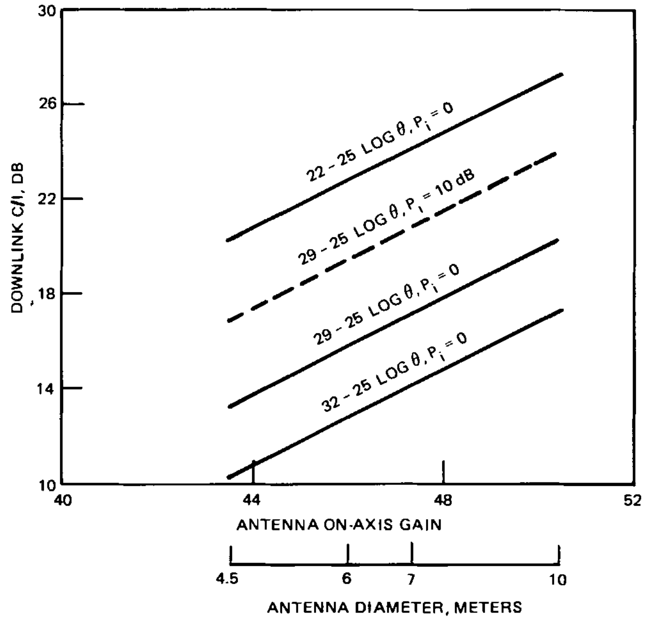


FIGURE 2. DOWNLINK C/I VERSUS ANTENNA GAIN FOR VARIOUS SIDELOBE ENVELOPES (2° SPACING)

The formula for downlink C/I can now be expressed as:

$$(C/I)_D = EIRP_{SAT} + G_{ES} - \sum_{i=1}^{N} \oplus \left[(EIRP_{SAT} + 3) + G_{ES}(\theta)_i + F_i \right] dB$$

Assuming F_i to be -6.5 dB, which is a worst case situation in which FM-TV is in all adjacent cross-pol channels, the curves of Figure 2 can be computed. It is obvious that the desired C/I can be obtained by using either a large antenna (high gain) or a smaller antenna with lower sidelobes. The lowest-cost choice, of course, is the latter.

SIDELOBES

Figure 3 shows the sidelobe contributors in a typical cassegrain antenna. A focal point antenna contains all these factors except for subreflector spillover. Both spillover contributors affect only the performance far-off the boresight. The other contributors affect close-in as well as far-out performance. Quantization of these contributors is within control of the antenna designer and the manufacturing process used.

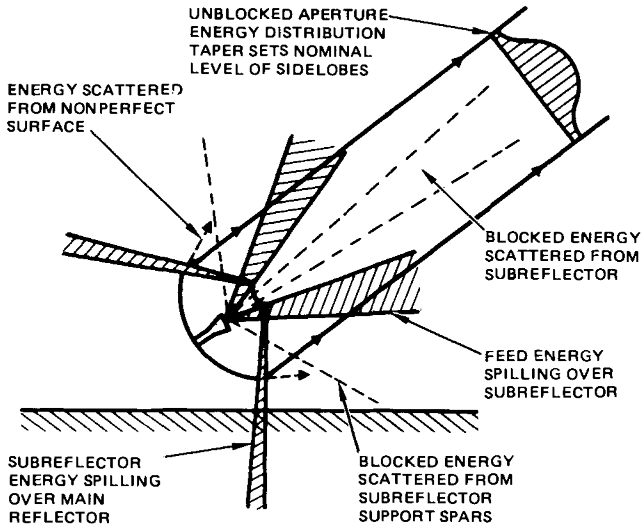


FIGURE 3. ANTENNA SIDELOBE CONTRIBUTORS

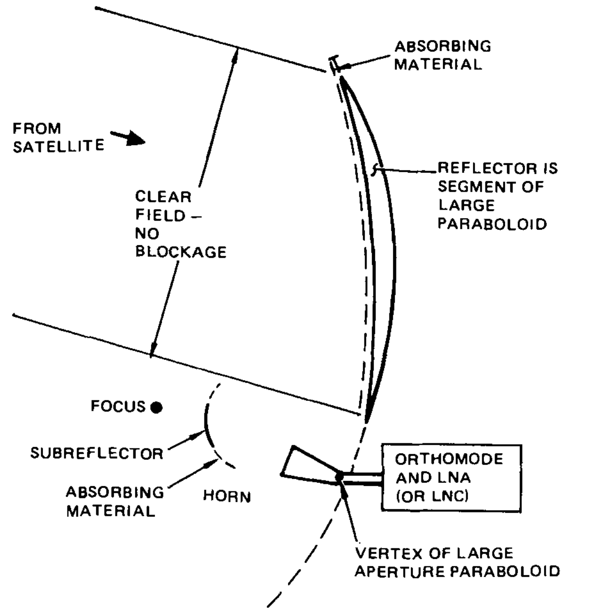


FIGURE 4. GEOMETRY OF OFFSET FEED, LOW SIDELOBE ANTENNA

Several approaches are available to antenna designers. The FCC lists the following options in the analysis section of the referenced rule-making proceeding[2]:

1. A reduction of antenna illumination lowers the main-beam gain slightly, but reduces the sidelobes considerably. The effectiveness of this technique increases with antenna diameter.

2. Corrugated antenna feeds have lower sidelobe levels.

3. Design practices can minimize re-radiation from secondary antenna reflector supports and antenna edges.

4. Off-set feed antenna designs reduce the effects caused by subreflectors and supports.

5. Horn antennas have lower sidelobes than parabolic dishes.

6. Improved manufacturing tolerances can reduce sidelobe levels resulting from the effects of antenna reflector surface errors.

In this author's opinion, all these options have merit and can achieve the performance level suggested by the FCC (i.e., envelope of 29-25 log θ). With the more conservative approach given above, however, small aperture antennas will need a better sidelobe envelope for an environment of 2° spacing. It is doubtful that any one of the approaches suggested by the FCC, if taken alone, will produce the desired result for antennas with a diameter of less than 10 meters at C-band.

For antennas less than 10 meters in diameter, an offset feed geometry is recommended. The offset feed provides a good deal of flexibility in the compromise between on-axis gain and sidelobe levels (aperture illumination) because there is no aperture blockage. In addition, a dual reflector design, either cassegrain or gregorian, is recommended so that the main beam cross-polarization isolation can be maintained at a high level. Figure 4 shows the geometry of a typical offset feed antenna. This type of antenna has been described in a number of technical articles[3,4].

CONCLUSIONS

To cope with a C-band satellite constellation with 2° spacing, CATV receiving antennas will need improved sidelobe performance. A conservative system approach indicates that the FCC proposed performance standard will not be adequate for small aperture antennas, especially with nonhomogeneous space segment. An offset feed antenna configuration can be implemented at reasonable cost to produce the desired sidelobe performance with an aperture of 4.5 meters diameter or less.

FOOTNOTES

1. Orbit Deployment Plan, 84 FCC 2d 584 (1981).

2. Licensing of Space Stations in the Domestic Fixed-Satellite Service and Related Revisions of Part 25 of the Rules and Regulations, FCC 81-466, released 18 November 1981, Docket No. 81-704.

3. Japan, An Example of an Antenna Configuration for Efficient Utilization of the Geostationary Satellite Orbit, CCIR Report 390-3, 453-2.

4. B.H. Burdine and E.J. Wilkinson, "A Low Sidelobe Earth Station Antenna for the 4/6 GHz Band," Microwave Journal, November 1980.