

THE IMPACT OF 3° SPACING ON CABLE TELEVISION

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ABSTRACT

This paper discusses the impact of 3° orbital spacing upon satellite distribution of cable television programming. Included are preliminary results of:

- Experiments designed to establish an appropriate protection ratio for cable video transmissions.
- Calculations indicating expected levels of interference at 3° spacing.

The conclusions of these exercises indicate that a 3° orbital spacing for C-band domestic satellites will not have a deleterious impact upon program distribution to existing (4.5 meter) cable earth stations. Recommendations are made concerning appropriate protection ratios, use of 3 meter antennas and optimum spacecraft deployment schemes.

INTRODUCTION

The Federal Communications Commission, in December 1980, dramatically set a course for the domestic satellite business. Its grants of orbital assignments and launch authorities provide a framework encouraging the orderly development of our industry. Among the issues addressed by the Commission's order was the recognition that the geosynchronous orbital arc is a finite resource that must be used efficiently. One approach to satisfying this requirement is reduction of spacing between adjacent C-band satellites from the present 4° to 3°.

This paper examines the impact of such a reduced spacing upon cable television distribution via domestic satellites.

ENGINEERING CONSIDERATIONS

The most important measure of picture quality in a satellite television link is signal-to-noise (S/N) defined as the ratio,

in dB, of the peak-to-peak picture (luminance) signal to RMS weighted noise. Expressed in equation form by:

$$S/N = C/N + FMI \quad (1)$$

where

S/N = signal-to-noise ratio

C/N = carrier-to-thermal noise ratio in the link

FMI = frequency modulation improvement

Typically, cable television systems operating with current United States domestic satellites realize an S/N on the order of 50.0 dB at the earth station. The primary determinants of C/N are the thermal noise contributions of the up and downlinks of the satellite system; however, the video receiver at a cable earth station is also exposed to the interfering effects of undesired signals which may simultaneously occupy the same bandwidth as the desired carrier (see Figure 1).

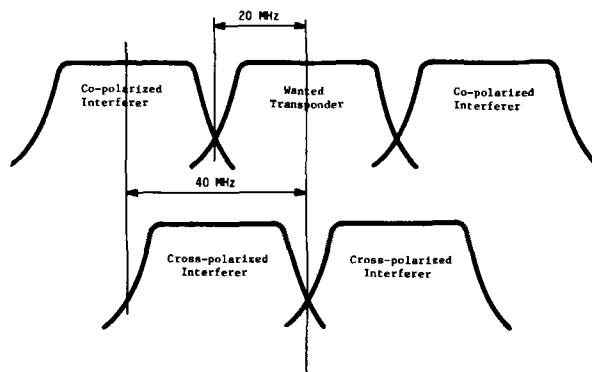


Figure 1

Transponder Frequency and Polarization Plan

These originate from three major sources:

- Internal interference (C/I_{int}) within the satellite caused by noise or signals in adjacent or cross-polarized transponders which penetrate into the desired transponder. The level of this interference is established by the skirt selectivity of the transponder filters and the cross-polarization performance of the earth-satellite link.
- Terrestrial interference (C/I_{terr}) from microwave systems operating in the 4 GHz band.
- Adjacent satellite interference (C/I_{adj}) from co-frequency signals of neighboring satellite systems, the level of which is primarily a function of the receiving antenna's off-axis discrimination.

Total carrier-to-interference (C/I_{tot}), defined as the ratio, in dB, between the power of the wanted signal and the power of all interfering signals as measured at the input to the earth station receiver, is expressed in equation form as:

$$(C/I_{tot}) = C/I_{int} \oplus C/I_{terr} \oplus C/I_{adj} \quad (2)$$

where

C/I_{int} = 26 dB for frequency reuse spacecraft

C/I_{terr} = 25 dB the typical level for which frequency coordination is accomplished

C/I_{adj} = adjacent satellite interference

\oplus = power summation

This paper examines the (C/I_{adj}) ratio with 3° spacing and its impact upon cable video transmissions.

The next section presents results of subjective testing accomplished at the RCA Laboratories for the purpose of establishing reasonable protection ratios (minimum required C/I_{tot}) for cable video services.

PROTECTION RATIO

An appropriate protection ratio for cable television services can only be determined via extensive subjective testing. The unique nature of the color video signal, and the complex physiological and

psychological processes involved in human perception of color images combine to make the effect of an interfering signal on a color television transmission analytically intractable and highly subjective, i.e., viewer dependent.

RCA has ongoing programs investigating the nature and characteristics of video signals. The most recent efforts explored subjective judgments of color video interference effects by groups of viewers. This involved controlled introduction of various types and levels of interfering signals as viewers indicated on data sheets the points associated with:

- Just Perceptible Interference (JPI), defined as that level in which the viewer first notices an anomaly in the picture.
- Just Objectionable Interference (JOI), defined as that level at which the viewers will turn off a program they desire to watch because the picture is intolerable.

A description of the test conditions and results follows. Note that data reduction efforts are still under way and the results presented here are preliminary.

TEST CONDITIONS

Wanted Signals (all with audio sub-carrier and energy dispersal):

- (1) Still slide (red flower on green background)
- (2) High quality video tape (Rose Bowl Parade)
- (3) EIA Standard color bars

Interfering Signals:

Full Transponder:

- (1) Full transponder FDM/FM (1872 channels)
- (2) EIA Standard magenta field
- (3) EIA Standard color bars
- (4) Off-air scenes

Narrowband:

- (1) 56 kbps BPSK

Transmission parameters used for the wanted signals (all located in the center of the transponder) were:

	Peak Deviation (MHz)	IF BW (MHz)	C/N (dB)
Case I:	10.8*	30	11.9
Case II:	10.8*	30	15.9
Case III:	6.7	17.5	19.2
Case IV:	6.7	17.5	25.2

*Presently used for Satcom video transmissions

Tests were conducted at the RCA Laboratories in a dark room. All signals were displayed on a 25" RCA XL-100 television set. Viewers were seated 4 - 6 feet from the screen.

There were ten participants; five male and five female. Of the total, two were expert and the remainder were inexperienced viewers.

Experimental Results (Preliminary)

Full Transponder Interferers:

	<u>Cases</u>			
Average Required C/I (dB)	I	II	III	IV
JPI	14.6	15.9	18.6	17.7
JOI	5.7	3.9	6.3	5.5

Narrowband Interferer:

	<u>Cases</u>			
Average Required C/I (dB)	I	II	III	IV
JPI	19.5	19.3	21.9	21.3
JOI	11.4	7.6	13.1	11.1

PRELIMINARY CONCLUSIONS OF SUBJECTIVE TESTING

- A protection ratio (C/I_{tot}) of approximately 18.0 dB would be satisfactory for cable television service.
- Narrowband signals were found to be the worst interferers requiring, on average, the highest protection ratios. However, the level of narrowband signals in operational systems

is considerably below the power which might introduce interference in adjacent satellite transmissions because such signals operate with substantial transponder backoffs.

- Reduction of the peak deviation from 10.8 MHz in Cases I and II to 6.7 MHz in Cases III and IV resulted in a greater susceptibility to interfering signals. Pursuing this, we ran some abbreviated tests using overdeviation techniques (peak deviation 13.7 MHz) and discovered that the required C/I for Just Perceptible Interference was reduced (improved) by 8.0 dB. Changing Satcom video transmission parameters to make the signal more rugged and less susceptible to interference may be appropriate. More experiments are planned on this point.
- Waveform monitors show the effects of interfering signals well before (10 dB) the picture does. Protection ratios predicated upon meeting parametric measurements would need to be considerably higher than the recommended level of 18.0 dB.

ADJACENT SATELLITE INTERFERENCE

Figure 2 illustrates the mechanisms

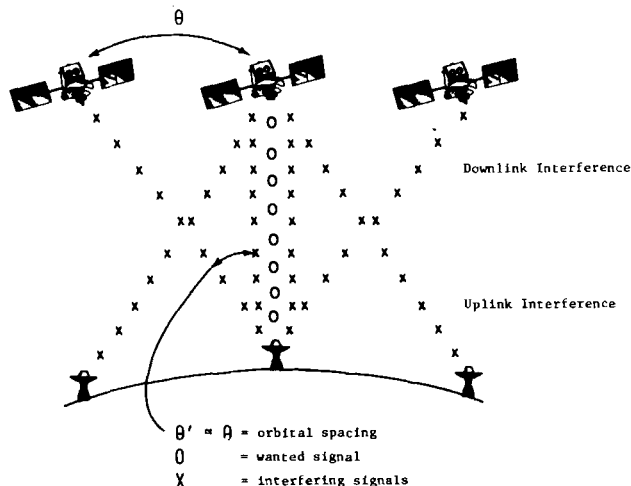


Figure 2

Interference Mechanisms

of adjacent satellite interference. There are two contributions:

- Uplink interference occurs by virtue of the finite gain of transmitting antennas in the direction of an adjacent satellite illuminating the receiving system in the wanted

spacecraft. This energy is then re-radiated into the receiving earth station.

- Downlink interference occurs by virtue of the finite gain of the receiving earth station in the direction of an adjacent satellite.

Clearly, a most critical parameter is the earth station antenna discrimination, the ratio in dB between maximum gain on boresight and gain in the direction of an adjacent spacecraft. Earth station antenna gain decreases monotonically with increasing angle off boresight (the FCC requirement is $32-25 \log \theta$, where θ is the angle off-axis). Thus, greater separation between satellites implies greater discrimination and concomitantly lower interference.

There also exists a cross-polarization advantage of approximately 4 - 6 dB in the off-axis (sidelobe) region of earth station antennas. This compares to 30 - 40 dB cross-polarization discrimination on-axis. An antenna oriented to receive a given transponder from a spacecraft (e.g. horizontal) will attenuate the energy of a co-frequency transponder in an adjacent satellite in accordance with the $32-25 \log \theta$ characteristic; however, if the co-frequency transponder is orthogonally polarized (e.g. vertical) it will encounter an additional attenuation of 4 - 6 dB.

Frequency plans of 24-transponder satellites utilize staggered transponder center frequencies to minimize internal interference (see Figure 1).

This ameliorates the interfering effect of frequency interleaved transponders in adjacent satellites as well. Additional improvement for television transmission is realized because the bulk of the energy in a video signal is concentrated near the center of the transponder at the carrier frequency.

EXPECTED INTERFERENCE LEVELS

The expected total C/I ratio for 4.5 meter facilities at 3° satellite spacing is 17.2 dB (see Table 1). This assumes no advantage due to cross-polarization discrimination (XPD) in the sidelobe region. The subjective testing discussed previously indicates that this would provide satisfactory performance for cable television distribution via satellite. Thus, the impact of 3° spacing on 4.5 meter cable systems would be a modest reduction in system margins with no

perceptible degradation of the video signal.

Off-axis cross-polarization discrimination of cable earth stations offers a means of recovering lost system margin. Optimum placement of satellites at 3° spacing would call for spacecraft having orthogonal polarizations and frequency interleaved transponders on uplinks and downlinks to be located adjacent to one another, i.e., Transponder 10 on one satellite would be horizontal on the uplink and vertical on the downlink, whereas in the adjacent spacecraft Transponder 10 would be vertical on the uplink and horizontal on the downlink. Table 1 shows total C/I ratios that could be expected as a function of off-axis XPD for 4.5 meter and 3.0 meter antennas and a beam edge EIRP of 33.0 dBW (provided by RCA Satcom III-R at 131° for all CONUS except southern Texas, Florida and New England). By way of comparison, the predicted C/I_{tot} , assuming no XPD advantage for 4.5 meter earth stations at 4° spacing, is 19.2 dB.¹ Therefore, while 4.5 meter dishes will provide satisfactory performance at 3° spacing, margin can be recovered as a function of XPD off-axis and it makes a dramatic impact upon performance with 3 meter antennas.

RCA plans further studies on the subject of interference to and from video signals. Of particular interest is an evaluation of the impact of high-speed (50 Mbps) services on orbital spacing.

Table 1

BEAM EDGE EIRP

33 dBW

3° Satellite Spacing

Cross Polarization

Discrimination (off-axis)	<u>4.5m</u>		<u>3.0m</u>	
	<u>C/I_{adj}</u>	<u>C/I_{tot}</u>	<u>C/I_{adj}</u>	<u>C/I_{tot}</u>
0	18.8	17.2	14.2	13.6
4	22.3	19.4	18.0	16.7
6	23.8	20.1	19.8	17.9

1. Declaratory Ruling and Order, Federal Communications Commission, 15 DEC 1976, Authorization of Receive-Only Small Earth Station Antennas.

CONCLUSIONS

- Spacing domestic C-band spacecraft at 3° will not degrade cable television distribution via satellite to 4.5 meter facilities. System margins will be slightly reduced but overall performance will be satisfactory.
- Cross-polarization discrimination (XPD) in the sidelobe region of earth station antennas offers a means of improving system margins at 3° spacing. Modest levels of XPD provide significant improvement in protection ratios. Optimum orbital deployment for use of this feature calls for adjacent satellites to be completely cross-polarized relative to one another on both up and downlinks and to be homogeneous, i.e., to have approximately the same EIRP.
- Three-meter antennas will not provide satisfactory protection ratios with 3° satellite spacing unless off-axis discrimination of these antennas is superior to the FCC minimum of $32-25 \log \theta$.
- Revising video transmission parameters (overdeviation) offers a means of reducing susceptibility of video signals to interference.

ACKNOWLEDGMENT

Many thanks to R. Dombroski, M. Freeling, K. Lanza, and R. Rosensweig, all of RCA Americom Technical Operations, whose efforts made this study and paper possible.