ATV SYSTEMS ASPECTS AND PLANNING FACTORS

Investigation Report

by

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1. Introduction

Following a request by the Broadcasting Regulation Branch of DOC, an investigation of the systems aspects of the proposed digital advanced television (ATV) simulcast systems was undertaken during the second quarter of 1992 in view of establishing the values of the critical parameters for planning purposes. The results of a detailed review of the ATV systems parameters is presented with an interpretation of the parameter values for planning purposes. The parameters of a typical ATV receiving installation are identified and linked analytically to establish (with more accuracy than in the case of NTSC) a reference ATV receiver model to be used for the planning of ATV broadcasting services. A fully flexible Lotus-123 spreadsheet has been created which ties all the key system parameters together in order to allow for a complete trade-off analysis among all the related system parameters in view of establishing optimum co-channel separations between ATV and NTSC transmitters. Finally, a list of assumptions that will have to be made to allow the planning of the service is tentatively established, in this case, resulting in more questions than answers.

2. ATV Systems Parameters

The appended Table 6 summarizes the published parameters of the four digital ATV systems as they are known today. For all these systems, it is clear that the performance values (ie. C/N and C/I's) are only as claimed by the proponents and may be subject to change based on the results of the ATTC and ATEL tests. Meanwhile, these values are felt to be representative and can be used for preliminary planning exercises.

Table 6 is divided into Source Coding parameters and Channel Coding parameters. The first group gives an indication of the theoretical performance of the video coding schemes. The second group gives an indication of the channel coding schemes used and their expected performance. The key parameters as far as planning is concerned are the four last ones: C/N and co-channel C/I requirements. Values for adjacent channel and taboo channel C/I's will only be available from the laboratory tests.

3. Television Receiver Model

An accurate model of a typical receiving installation needs to be developed in order to investigate the optimum set of parameters for receiving ATV. Unlike NTSC where man-made noise was considered but not included in the actual calculations of the minimum field strength, in the case of ATV receivers where a much lower noise front-end could be used in the future, man-made noise needs to be carefully handled since it will likely become a more important factor in the calculation of the required field strength. Existing technology already allows for low cost low-noise receiver front-end. A more accurate model is therefore proposed for the television receiving installation (see Figure 1):

3.1 NTSC Receiver Model:

A more detailed set of equations is proposed to model a typical television receiving installation. These equations take into account the effect of man-made noise and antenna coupling losses. First, the figure of merit of the receiver can be calculated with the following formula: (Ref. CCIR Rep. 473-4, Annex I)

$$G/T = 10 \log \left[\frac{\alpha \times 10^{Gi/10}}{\alpha T_a + (1-\alpha)T_0 + (10^{NF/10}-1)\,T_0} \right] \qquad (dB(1/K))$$

where:

G_a = antenna gain in decibels (dB) (referenced to a dipole)

G_i = antenna gain referenced to an isotropic source (dBi)

$$G_i = G_a + 2.15 \text{ dB}$$

L = downlead losses in dB

α = downlead losses in power ratio

$$\alpha = 10^{-L/10}$$

T_0 = reference temperature = 290 K

T_a = effective antenna temperature, expressed in degree Kelvin, assumed to be equal to the ambient man-made noise temperature where F is the frequency in MHz (Ref. CCIR Rep.258-4, Fig.1, rural case) plus half of the ground temperature since it is expected that half of the receiving antenna pattern will be directed towards the ground:

$$T_a = 290 \times (10^{(6.63-2.77 \log(F))} + 145) \qquad \text{(K)}$$

NF = receiver noise figure in dB (normally assumed to be 15 dB for NTSC receivers)

Then, the power flux-density (PFD) required at the receiving site to produce a given Carrier-to-Noise ratio (C/N) is given by the following formula: (Ref. CCIR Rep 215-6, sec. 3.5)

$$PFD = C/N - G/T + 10 \log(kB) + 10 \log(4\pi/\lambda^2) \qquad (\text{dB(W/m}^2))$$

where:

k = Boltzman constant (10 log(k)= -168.6 dB(W/(KxMHz))

B = system equivalent noise bandwidth (e.g., NTSC= 4 MHz)

λ = wavelength in metre

The required field strength is related to the power flux-density as follows:

$$E = PFD + 145.8 \qquad (\text{dB}(\mu\text{V/m}), \text{ later noted as dBu})$$

The results of a parametric study done over the VHF and UHF TV bands and using the conventional NTSC parameters in the above equations are given in the appended Table 7. The assumed NTSC parameters are as follows:

C/N = 30 dB
Bandwidth = 4 MHz

	low VHF	high VHF	UHF
Antenna Gain (G)	6 dB	6 dB	13 dB
Downlead Losses (L)	1 dB	2 dB	5 dB

Table 1: Assumed NTSC receiver antenna gain and downlink loss

It can be found from Table 7 that at 645 MHz and for 15 dB receiver noise figure, the required field strength is 60.3 dBu. This corresponds to the 64 dBu value widely used for TV planning (grade B contour) and stated in O'Connor's paper[1] when the factor correcting from F(50,50) to F(50,90) service availability is added. However, in this case, the effects of man-made noise and coupling losses are more carefully taken into account. At 195 MHz (high VHF), the required field strength is 51 dBu at the assumed receiver noise figure of 12 dB. This corresponds to 56 dBu as in O'Connor's paper[1] when the 5 dB F(50,90) correction factor is added. At 69 MHz (low VHF), the assumed noise figure is also 12 dB and the required field strength is found to be 45 dBu, which results in 51 dBu when the 6 dB F(50,90) correction factor is added rather than 47 dBu as currently used for planning[1]. This shows that the 47 dBu value used for planning VHF TV services is somewhat marginal (by 4 dB) when the ambient "rural" man-made noise is considered in the calculations (see CCIR Rep. 258-4).

Table 7 also shows the effect of varying the receiver noise figure on the signal field strength required at the receiving site. It can be seen that, as expected, the man-made noise is clearly predominant in the low VHF band where a variation in receiver noise figure barely changes the required field strength. However, in the UHF band, the receiver noise becomes predominant and the field strength is clearly determined by the receiver noise figure (i.e., 1 dB improvement in noise figure reduces the required field strength by 1 dB). This proves that the receiver noise figure is the determinant factor in setting the required transmitter power in the UHF band.

3.2 ATV Receiver Model:

In the case of an ATV installation, advantage can be taken of a more accurate modelling of some elements of the installation. This will also allow for a better optimization of the key parameters in a view to improving the performances of the ATV receiving installation. A second parametric study was done assuming the following parameters:

antenna gain in dB (G_a). It is found that the 6 dB gain for the VHF band as assumed for NTSC is reasonable. It is in fact representative of a three element Yagi-Uda antenna. However, the 13 dB gain assumed at UHF seems to be rather demanding. This requires a rather complex multi-element antenna with multi-element reflector to secure the 13 dB gain across the entire UHF band. Such complex antenna will tend to increase the wind loading and thus the complexity of the receiving installation. An antenna gain of 10 dB seems more reasonable at UHF and will be assumed in this exercise.

download losses in dB (L). A more accurate modelling of this parameter in now possible. It is assumed that in most receiving installations, a 75Ω coaxial cable will be used to bring the RF signal to the ATV receiver. The main elements contributing to these losses will be as follows:

$$L = L_b + L_c + L_f$$

where:

L_b = 0.5 dB (balun: 300/75 Ω matching transformer)

$L_c = 15/30.48 \times (-0.175 + 0.277\sqrt{F})$

Coaxial cable loss as a function of frequency in MHz (F) for 15 m cable length (10 m for the antenna mast and 5 m in-house cable run). It is assumed that the coaxial cable will be of the type used by cable industry for subscriber drops (RG59/U). [Typical RG59/U losses: Current Cable Installation Practices].

L_f = 1 dB

Receiver pre-selection filter insertion loss. Some ATV proponents suggest that some switchable pre-selection filters may be needed in the first stage of the low-noise amplifier to reduce the effect of intermodulation with high power NTSC carriers.

The appended Table 8 gives the results of this second parametric exercise with the more refined model of the ATV receiving installation. The ATV system parameters assumed for the purpose of this exercise are those suggested by General Instrument[2] for their 32-QAM system (see appended Table 6):

C/N = 16.5 dB
Bandwidth = 5 MHz

As can be seen from Table 8, the required field strength for ATV reception is markedly less than that needed for NTSC. It is also important to note that for most of the high VHF and the UHF bands, a 1 dB improvement in receiver noise figure corresponds to 1 dB less field strength required at the receiving site.

3.3 Optimum Receiver Noise Figure

There is a relatively large flexibility in setting a range of values for the ATV receiver noise figure with the current technology. The use of Gallium-Arsenide technology for the low-noise first stage of amplification has allowed the mass production of low-noise amplifiers for consumer satellite reception (TVRO's) at 4 GHz and 12 GHz with noise figures in the range of 1-3 dB. This should be even more easily achievable at lower frequency in the UHF band, although unlike in the satellite case, there is some trade-off needed between the noise figure and the dynamic range of the first amplification stages due to the presence of nearby high power NTSC transmitters. It is anticipated that noise figures in the range 3-10 dB would be achievable with only a marginal increase in complexity/cost of the ATV receivers bearing in mind the expected complexity of the signal processing circuits that will be needed in these ATV sets.

The ATV receiver noise figure is a very important parameter to be optimized. It allows a possible variation of the ATV transmitter power for a given received C/N, thereby allowing for a balance of the interference from ATV into NTSC and NTSC into ATV since the power differential between these two types of transmissions can be adjusted by this parameter.

Table 2 gives typical protection ratio values for all combinations of ATV and NTSC co-channel interference. The values published by General Instrument[2] are used for the purpose of this exercise. As indicated, the protection ratio for interference from ATV into NTSC is 30 dB (corresponding to the required C/N for NTSC since the ATV signal is expected to be seen as noise by an NTSC receiver). However, it is found that the ATV receivers are much more immune to NTSC interference, resulting in a range of claimed protection ratios "NTSC into ATV of" -2 dB to 6 dB, depending on the ATV system (note that these protection ratios are defined as ATV RMS power over NTSC peak power. This means that if the same availability criteria (desired= 90% of the time and undesired= 10% of the time) are used for both NTSC and ATV, the ATV transmissions could be between 12 dB (i.e., (30-6)/2) and 16 dB lower power than the NTSC transmissions depending on the ATV system. This describes the situation where the separation distances between NTSC and ATV transmitters would be constrained equally in both directions (i.e., from ATV interference into NTSC and NTSC interference into ATV). Such reduction in ATV transmit power is possible because of the lower C/N required by ATV systems and also by assuming ATV receivers would have lower noise figures, in the case of this example, 10 dB to 7 dB at 800 MHz. The more robust an ATV system is to NTSC interference, the lower the receiver noise figure can be for a more optimum spectrum usage. In other words, in order to take full advantage of the robustness of digital transmission schemes against interference, the receiver noise figure needs to be set to a lower value at the planning stage. Any more demanding requirement in terms of service availability against noise or interference would result in lower optimum values for the receiver noise figure.

4. Discussion on Planning Parameters

Taking the General Instrument system[2] as an example, the parameters required for planning can be summarized as follows:

C/N= 16.5 dB

resulting in a required minimum field strength of 45.5 dBu at 645 MHz if a receiver noise figure of 10 dB is assumed. Given the extent of coverage (grade B contour similar to NTSC Class-C station (30 dBkW and EHAAT of 300 m)) and the service availability at the edge of the coverage of areas of F(50,90), the power of the ATV transmitter can be established. The service availability may need to be higher for ATV because of the abrupt failure mode of digital ATV systems.

The interference situation for the General Instrument System[2] can be summarized in Table 2:

		Interfered with	
		NTSC	ATV
Interferer	NTSC	28 dB	5 dB
	ATV	30 dB	16 dB

Table 2: Protection ratios for a typical ATV system

Separation distances can be calculated for a given service availability at a given distance in the grade B contour. In Canada, the grade B contour is fully protected whereas in the US, there is a tendency to protect only up to a distance from the transmitter equivalent to about 75% of the grade B contour radius. This corresponds to about 14% of the grade B area not protected. The transmitter separation distances are based on F(50,50) availability of the wanted NTSC signal and F(50,10) availability of the interfering NTSC signal. Since the transition to outage for digital ATV systems is expected to be more abrupt for noise and interference, these availability figures may need to be tighter.

As an example, F(50,90) or even F(50,97) may need to be used for the wanted ATV signal whereas F(50,10) and even F(50,3) may need to be used for the interfering ATV and NTSC signal. In fact the apportionment of noise and interference on the edge of the contour needs to be addressed since interference, in many cases, will be perceived as an increase in noise at the receiver. It is suggested that leaving a margin in dB for such apportionment may not be as appropriate as using tighter time availability criteria such as F(50,97) for the wanted signal and F(50,3) for the interfering signal. These new availability figures for ATV need to be clarified before any planning exercise can be considered as final.

Different time availability objectives can be considered by simply using the F(50,50) and F(50,10) points that can be found in the FCC Tables as two reference points on a log-normal distribution (which was found to be valid with respect to the time variation), therefore allowing interpolation and extrapolation for other time availability according to the following formula[3]:

$$F(50,T)= F(50,50) + k(T) \times [F(50,10)-F(50,50)]/1.282 \qquad \text{(dB}\mu\text{V/m relative to 1 kW of ERP)}$$

where k(T) is as follows:

T(%)	90	91	92	93	94	95	96	97	98	99
k(T)	-1.282	-1.341	-1.407	-1.476	-1.555	-1.645	-1.751	-1.881	-2.054	-2.326
T(%)	1	2	3	4	5	6	7	8	9	10
k(T)	2.326	2.054	1.881	1.751	1.645	1.555	1.476	1.407	1.341	1.282

Table 3: Normalization factors for the log-normal distribution

In order to allow the calculation of the separation distances between transmitters, an important assumption needs to be made regarding the receiving antenna front-to-back ratio. It is suggested that for the case of the NTSC receiver, the usual 6 dB can be assumed in all TV bands. However, a better performance, as found to be readily available with current antennas, can be assumed for the ATV receiving antenna. The values assumed are those given in CCIR Recommendation 419-2 (Mod I) as indicated in Table 4.

A simple exercise was made using the F(50,90) and F(50,10) criteria for the wanted and interfering signals respectively and this resulted in the matrix of separation distances given in Table 5, assuming a Class-C NTSC transmitter and the same extent of coverage for the ATV transmitter.

	NTSC	ATV
low VHF	6 dB	6 dB
high VHF	6 dB	12 dB
UHF	6 dB	16 dB

Table 4: Assumed receiving antenna front-to-back ratios

		Interfered with	
		NTSC	ATV
Interferer	NTSC	272 km	192 km
	ATV	215 km	186 km

Table 5: Required co-channel separation distances for the GI ATV system

As can be seen in this case, the balance of interference between the two types of systems is in favour of NTSC interference into ATV (i.e., "NTSC into ATV" separation distance is smaller than in the reverse direction) meaning that the ATV transmit power should be lower, hence the noise figure of the ATV receiver should be lower to permit a decrease of the ATV transmit power and still meet the C/N criterion. This would result in a more optimum and symmetrical interference situation. This is the case for all the proposed ATV systems as can be seen in the Tables of Appendix A which summarize the co-channel separation distances required by all proposed ATV systems. As can be seen, the N-MUSE system is included for the sake of completeness. This means that in all cases, a lower receiver noise figure than the assumed 10 dB should be used for a more efficient use of the spectrum. Furthermore, if the service availability criteria are changed, the noise figure value would probably need to be changed to still produce the optimum interference situation. This balance in interference between ATV and NTSC is used here as an optimal point but, since NTSC is bound to be shut down in the future, one could think of a different optimal point where the ATV coverage would suffer more in the mean time.

5. Spreadsheet for ATV system and coverage parameters trade-off study

To facilitate the study of the trade-off among parameters involved in establishing ATV system coverage and effects on existing NTSC allotments, a Lotus 1-2-3 spreadsheet was designed. The base propagation data is a digitized version of the classic FCC F(50,50) and F(50,10) curves. The user is afforded the opportunity to input the key system and coverage parameters for the NTSC and ATV services. The programme dynamically re-calculates the co-channel separation distances for the Desired and Undesired pairs of ATV/NTSC services.

For NTSC, the following parameters can be input by the user: effective radiated power (ERP), effective height above average terrain (EHAAT), minimum field strength (Emin), receiving antenna front-to-back ratio (F/B) and % of coverage area to be protected.

For ATV, the input parameters are: channel bandwidth, C/N, receiver noise figure (NF), Emin, % of time value (T) in the curve F(50,T) for ATV service availability, EHAAT, receiving antenna F/B ratio, % of time in the F(50,T) curve for allowable interference into ATV and % of the coverage area to be protected.

Appendix B to this document presents a detailed description of the software, along with examples of the output. The given examples reflect the cases given in Appendix A for optimum receiver noise figures.

6. Conclusion

There is a lot of questions that still need to be resolved before advanced planning exercises can be performed. Since simulcasting is the most likely ATV implementation scenario, it is worthwhile to spend the time to develop realistic system and planning assumptions at this stage rather than trying to rationalize it after the fact as seems to have been the case for NTSC. An effort was made in this study to establish the key ATV systems parameters and also rationalize the ATV receiving installation reference model. This resulted in realizing that the receiver noise figure is in fact a key parameter that can allow for better optimization of the spectrum usage rather than an arbitrary assumption as seems to have been the case so far in the various ATV planning efforts. This also resulted in the development of a spreadsheet that brings all the key elements needed to carry-out a trade-off study among system and coverage parameters in a view to minimize the co-channel separation distances.

Further work is required to arrive at a complete understanding of all the system and coverage parameters and their inter-relation. The spreadsheet that has been developed through this project should be used for this purpose. A number of critical questions also have to be addressed:

- should the ATV coverage match the Class-A -B or -C transmitters coverage?

- what should be the availability factor at edge of ATV coverage (e.g., F(50,90), F(50,97)?

- what should be the interference occurrence at edge of ATV coverage (e.g., F(50,10), F(50,3)?

- should there be a balance of interference between ATV and NTSC or should ATV suffer more in the mean time?

- should the ATV service contour be interference protected as for NTSC in Canada or could interference be allowed in the contour as assumed in the US exercises?

It is hoped that, in the process of planning the ATV service, early answers to these questions can be found.

7. References

1. R. O'Connor, "Understanding Television's Grade A and Grade B Service Contours," IEEE Transactions on Broadcasting, VOL. BC-14, No. 4, December 1968

2. General Instrument Corporation, VideoCipher Division, "Digicipher HDTV System Description," Tech. Report. TM 62004, The American Television Alliance, August, 1991.

3. K. Blair Benson, Television Engineering Handbook, McGraw-Hill, 1986.

TABLE 6: DIGITAL ATV SYSTEMS

Source Coding

	Zenith/AT&T	ATRC	GI	MIT/GI
N.Lines	787.5	1050	1050	787.5
N.Pixels	1280	1440	1408	1280
ColorRes.	1/2,1/2	1/2,1/2	1/4,1/2	1/2,1/2
Interlace	1:1	2:1	2:1	1:1
A.R.	16:9	16:9	16:9	16:9
Source coding	MC/DCT	MC/DCT MPEG++	MC/DCT	MC/DCT
Audio	4 ch	4 ch	4 ch	4 ch
Ancillary data capacity (kbit/s)	413	256	252	252

Channel Coding

	Zenith/AT&T	ATRC	GI	MIT/GI
Modulation	2/4 VSB	32 QAM	32(16) QAM	32(16)QAM
Video Rate (Mbit/s)	8.5-17	17.75	17.47(12.59)	18.88(13.6)
FEC (Mbit/s)	RS 1.15-2.3	RS+9/10 Trel. 5.46	RS+4/5 Trel. 6.17	RS+4/5 Trel. 6.54
Total Rate (Mbit/s)	11-21	24	24.39(19.51)	26.43(21.15)
Equalizer(μsec)	-4,+19	-4,+4	-2,+24	-2,+24
Noise BW (MHz)	6	6	5	6
C/N (dB)	10/16	16.1	16.5(12.5)	15.7(11.7)
C/I $_{NTSC-ATV}$	-6/0	-2	5 (0)	6(0)
C/I $_{ATV-NTSC}$	30	30	30	30
C/I $_{ATV-ATV}$	10/16	16.1	16 (12)	15.2(11.2)

NOTES:

(1). The Zenith/AT&T system uses a dual modulation scheme: 2-level VSB and 4-level VSB. The proportion of 2-level and 4-level data, and consequently the data rate and system performance, will vary according to scene complexity.

(2). ATRC, GI and MIT/GI's systems have a dual mode of operation: 32-QAM and 16-QAM. In all cases, the primary mode is 32-QAM and the mode is selected at the encoder.

(3). ATRC uses a two carrier system. One carrier has one fourth of the bit rate, and carries priority information. The other carrier handles the remaining information. It is transmitted at 5 dB lower power.

(4). C/I $_{NTSC-ATV}$ denotes average ATV power to peak NTSC power, ATV being the desired signal.

(5). ATV carrier level refers to the average power.

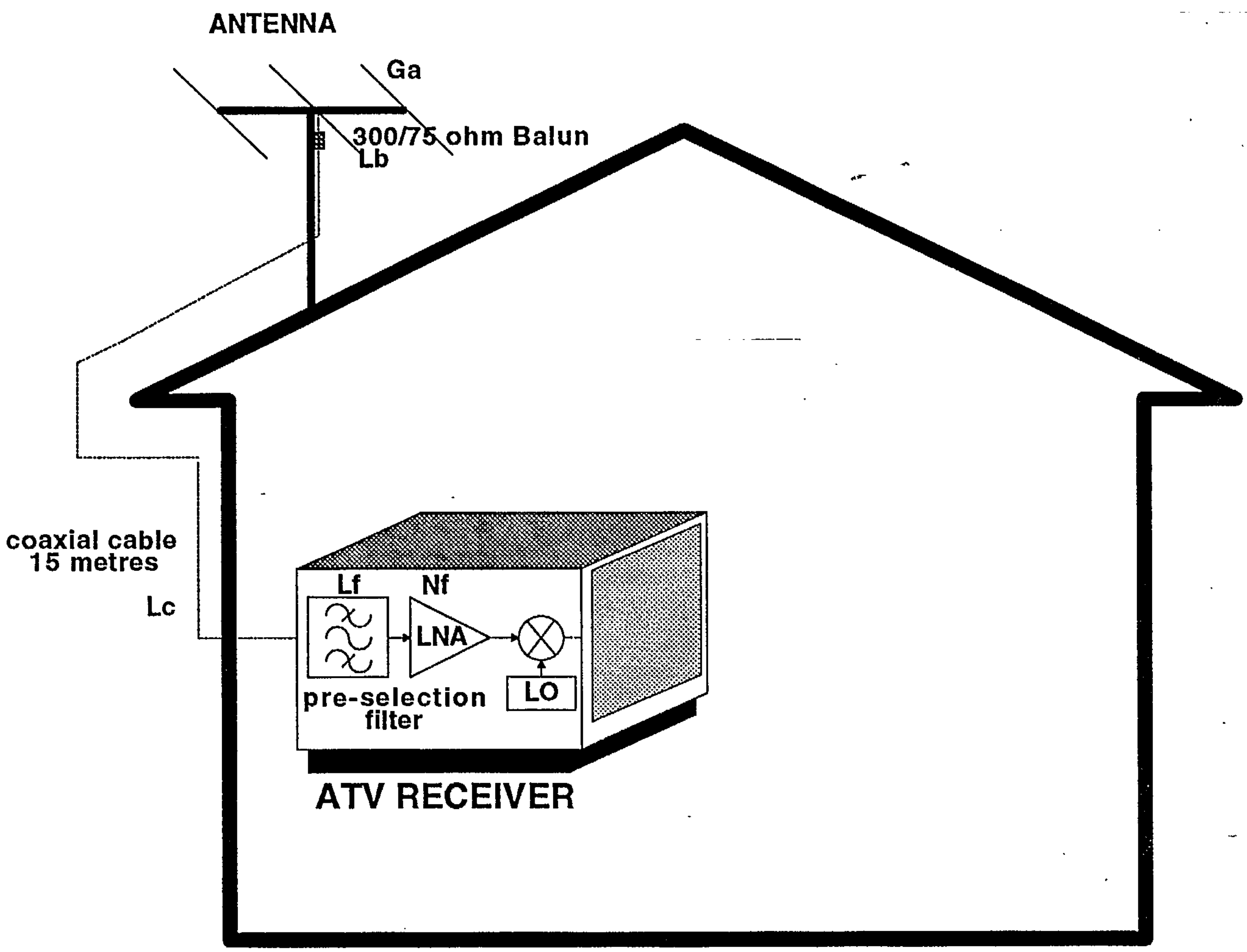

FIGURE 1: ATV REFERENCE RECEIVING INSTALLATION

		Low VHF			High VHF			UHF			
Channel		2	4	6	7	10	13	14	27	43	69
Frequency	(MHz)	57.0	69.0	85.0	177.0	195.0	213.0	473.0	551.0	645.0	803.0
Gain (dB)		6	6	6	6	6	6	13	13	13	13
Loss (dB)		1	1	1	2	2	2	5	5	5	5
	1	44.0	43.4	42.8	42.2	42.3	42.5	43.3	44.5	45.8	47.7
N	2	44.0	43.5	42.9	42.7	42.9	43.2	44.3	45.6	46.9	48.8
O	3	44.1	43.5	43.0	43.3	43.6	43.9	45.4	46.7	48.0	49.9
I	4	44.1	43.6	43.2	43.9	44.3	44.7	46.5	47.7	49.1	51.0
S	5	44.2	43.7	43.3	44.6	45.0	45.5	47.5	48.8	50.1	52.0
E	6	44.2	43.8	43.5	45.3	45.8	46.4	48.5	49.8	51.2	53.1
	7	44.3	44.0	43.7	46.1	46.7	47.2	49.6	50.9	52.2	54.1
F	8	44.4	44.1	44.0	46.9	47.5	48.1	50.6	51.9	53.2	55.1
I	9	44.6	44.3	44.3	47.8	48.4	49.1	51.6	52.9	54.3	56.2
G	10	44.7	44.6	44.7	48.6	49.3	50.0	52.6	53.9	55.3	57.2
U	11	44.9	44.9	45.1	49.5	50.2	50.9	53.6	54.9	56.3	58.2
R	12	45.2	45.2	45.6	50.4	51.2	51.9	54.6	55.9	57.3	59.2
E	13	45.5	45.6	46.2	51.4	52.1	52.9	55.6	56.9	58.3	60.2
(dB)	14	45.8	46.1	46.8	52.3	53.1	53.8	56.6	57.9	59.3	61.2
	15	46.2	46.6	47.4	53.3	54.1	54.8	57.6	59.0	60.3	62.2

TABLE 7: REQUIRED FIELD STRENGTH IN dB (uV/m)
AS A FUNCTION OF NTSC RECEIVER NOISE FIGURE
(C/N= 30 dB, B= 4 MHz)

		Low VHF			High VHF			UHF			
Channel		2	4	6	7	10	13	14	27	43	69
Frequency (MHz)		57.0	69.0	85.0	177.0	195.0	213.0	473.0	551.0	645.0	803.0
Gain (dB)		6	6	6	8	8	8	10	10	10	10
Loss (dB)		2.4	2.5	2.7	3.2	3.3	3.4	4.4	4.6	4.9	5.3
	1	31.5	31.0	30.5	28.3	28.6	28.9	33.0	34.6	36.2	38.5
N	2	31.6	31.0	30.6	28.9	29.3	29.7	34.1	35.7	37.3	39.6
O	3	31.6	31.1	30.7	29.5	30.0	30.5	35.2	36.7	38.4	40.7
I	4	31.7	31.2	30.9	30.2	30.8	31.3	36.3	37.8	39.4	41.7
S	5	31.8	31.4	31.1	31.0	31.6	32.2	37.3	38.9	40.5	42.8
E	6	31.9	31.5	31.4	31.7	32.4	33.1	38.4	39.9	41.5	43.8
	7	32.0	31.7	31.7	32.6	33.3	34.0	39.4	40.9	42.6	44.9
F	8	32.1	31.9	32.0	33.4	34.2	34.9	40.4	42.0	43.6	45.9
I	9	32.3	32.2	32.5	34.3	35.1	35.8	41.4	43.0	44.6	46.9
G	10	32.5	32.5	32.9	35.2	36.0	36.8	42.4	44.0	45.6	47.9
U	11	32.8	32.9	33.4	36.1	37.0	37.7	43.4	45.0	46.6	48.9
R	12	33.1	33.3	34.0	37.1	37.9	38.7	44.5	46.0	47.6	49.9
E	13	33.4	33.8	34.7	38.0	38.9	39.7	45.5	47.0	48.7	51.0
(dB)	14	33.8	34.4	35.3	39.0	39.8	40.7	46.5	48.0	49.7	52.0
	15	34.3	35.0	36.1	39.9	40.8	41.6	47.5	49.0	50.7	53.0

TABLE 8: REQUIRED FIELD STRENGTH IN dB (uV/m)
AS A FUNCTION OF ATV RECEIVER NOISE FIGURE
(C/N= 16.5 dB, BW= 5 MHz)

APPENDIX A

Zenith/AT&T (4 VSB)

NTSC (Class C)
Power= 30 dB(kW)
EHAAT= 300 m
Radius= 69.5 km
E_{min}= 64 dBu   F(50,50)

ATV
BW= 6 MHz
C/N= 16 dB
Power= 18.1 dB(kW)
EHAAT= 300 m
Radius= 69.5 km
E_{min}= 45.8 dBu   F(50,90), Noise Figure= 10 dB

Protection ratios:

		Interfered with	
		NTSC	ATV
Interferer	NTSC	28 dB	0 dB
	ATV	30 dB	16 dB

Wanted NTSC: F(50,50)
Interfering NTSC: F(50,10)
Wanted ATV: F(50,90)
Interfering ATV: F(50,10)
Coverage radius protected= 100%

Co-channel Separation Distances:

		Interfered with	
		NTSC	ATV
Interferer	NTSC	272 km	167 km
	ATV	217 km	186 km

ATRC (32 QAM)

NTSC (Class C)
Power= 30 dB(kW)
EHAAT= 300 m
Radius= 69.5 km
E_{min}= 64 dBu F(50,50)

ATV
BW= 6 MHz
C/N= 16.1 dB
Power= 18.2 dB(kW)
EHAAT= 300 m
Radius= 69.5 km
E_{min}= 45.9 dBu F(50,90), Noise Figure= 10 dB

Protection ratios:

		Interfered with	
		NTSC	ATV
Interferer	NTSC	28 dB	-2 dB
	ATV	30 dB	16.1 dB

Wanted NTSC: F(50,50)
Interfering NTSC: F(50,10)
Wanted ATV: F(50,90)
Interfering ATV: F(50,10)
Coverage radius protected= 100%

Co-channel Separation Distances:

		Interfered with	
		NTSC	ATV
Interferer	NTSC	272 km	159 km
	ATV	217 km	186 km

GI (32 QAM)

NTSC (Class C)
Power= 30 dB(kW)
EHAAT= 300 m
Radius= 69.5 km
E_{min}= 64 dBu F(50,50)

ATV
BW= 5 MHz
C/N= 16.5 dB
Power= 17.8 dB(kW)
EHAAT= 300 m
Radius= 69.5 km
E_{min}= 45.5 dBu F(50,90), Noise Figure= 10 dB

Protection ratios:

		Interfered with	
		NTSC	ATV
Interferer	NTSC	28 dB	5 dB
	ATV	30 dB	16 dB

Wanted NTSC: F(50,50)
Interfering NTSC: F(50,10)
Wanted ATV: F(50,90)
Interfering ATV: F(50,10)
Coverage radius protected= 100%

Co-channel Separation Distances:

		Interfered with	
		NTSC	ATV
Interferer	NTSC	272 km	192 km
	ATV	215 km	186 km

N-MUSE

NTSC (Class C)
Power= 30 dB(kW)
EHAAT= 300 m
Radius= 69.5 km
E_{min}= 64 dBu F(50,50)

ATV
BW= 6 MHz
C/N= 37.8 dB
Power= 39.9 dB(kW)
EHAAT= 300 m
Radius= 69.5 km
E_{min}= 67.6 dBu F(50,90), Noise Figure= 10 dB

Protection ratios:

		Interfered with	
		NTSC	ATV
Interferer	NTSC	28 dB	23.8 dB
	ATV	24.5 dB	31.3 dB

Wanted NTSC: F(50,50)
Interfering NTSC: F(50,10)
Wanted ATV: F(50,90)
Interfering ATV: F(50,10)
Coverage radius protected= 100%

Co-channel Separation Distances:

		Interfered with	
		NTSC	ATV
Interferer	NTSC	272 km	176 km
	ATV	311 km	270 km

APPENDIX B

CRC's "ATV-NTSC Co-Channel Separation Distance" Software (ATVCOSEP) (designed as a Lotus 1-2-3 .WK1 spreadsheet)

CRC has designed software to dynamically calculate the co-channel separation distances for pairs of ATV and/or NTSC stations. The software is designed as a .WK1 Lotus spreadsheet, which requires LOTUS 1-2-3 version 2.01 or higher. A copy of the electronic version of the spreadsheet can be made available on a computer diskette upon request to the authors. The user HOME screen of the spreadsheet is shown below:

```
        A    B    C    D    E     F     G     H     I     J      K      L

1     CRC ATV-NTSC Co-Channel Separation                  ATV
2     ~~~~~~~~~(Freq=645MHz)~~~~~~~~~~~~~  Bandwidth (MHz)  ~~~         5
3              ~~~~~~~~~~~~~          |  C/N (dB)                    16.5
4                    NTSC             |  Receiver NF=1-15 (dB)         10
5     ERP (dBK)      ~~~~~~       30  |  Emin (dBu/m)                45.5
6     EHAAT (m)                  300  |  F(50,T) T=50,90-99 (%)        90
7     Emin (dBu/m)                64  |  Radius (km)                69.48
8                                     |  EHAAT (m)                    300
9     F(50,50) Radius (km)     69.48  |  ERP (dBK)                   17.8
10    --------------------------------|-----------------------------------
11    RX antenna F/B ratio (dB)    6  |  RX antenna F/B ratio (dB)     16
12    Interference into NTSC F(50,10) |  Interference into ATV
13                                    |       F(50,T) T=1-10 (%)       10
14    % Cov. Radius protected    100  |  % Cov Radius protected       100
15    ====================================================================
16        Protection ratios (dB)        Co-channel separation distance (km)
17                  Desired                                    Desired
18                 NTSC    ATV                               NTSC    ATV
19    Undesired NTSC  28     5       HELP    Undesired NTSC  272.4 191.9
20              ATV   30    16      Pg Dn              ATV   215.1 185.6
```

"ATVCOSEP" HOME Screen
The input parameters are highlighted

INPUTS

The user can specify the following input parameters, which are highlighted on the above HOME SCREEN.

NTSC
- ERP (dBK)
- EHAAT (m)
- RX Antenna F/B Ratio (dB)
- % Coverage Radius Protected

NOTES:
1) NTSC service availability is fixed at F(50,50)
2) Interference into NTSC is fixed at F(50,10)
3) NTSC into NTSC Protection Ratio is fixed at 28dB

ATV
- Bandwidth (MHz)
- C/N Ratio (dB)
- Receiver Noise Figure (dB)

- Wanted F(50,T) where T can be either 50 or vary from 90 to 99%.

  NOTE: An assumption is made that field-strength varies as log-normal with T.
- Coverage Contour Radius (km)
- EHAAT (m)
- RX Antenna Front-to-Back Ratio (dB)
- F(50,T) Interference into ATV, where T can vary from 1 to 10%

  NOTE: An assumption is made that distance varies with T according to a Normal (Gaussian) distribution, for a given field-strength. This assumes a linear relationship between field-strength (in dB) and distance (in km), around the point of interest. This may result in some inaccuracies for low percentage of Time (eg 1%), but is acceptable as a first approximation.

- % Coverage Radius Protected
- Desired to Undesired Protection Ratios: NTSC into ATV
ATV into NTSC
ATV into ATV

OUTPUTS

The software dynamically calculates the following outputs and displays them in the appropriate area of the HOME Screen.

- NTSC F(50,50) coverage contour radius for the given field-strength
- ATV minimum field-strength (dBu/m)
- ATV Transmit Power (dBK)
- Co-channel Separation Distances (km)

SPREADSHEET PROPAGATION FUNCTIONS

The propagation data, on which the calculations are made, are a digitized version of the classic FCC/DOC F(50,50) and F(50,10) curves, for channels 14-69. (Linear interpolation was used to obtain inter-data values.) The following nine dedicated propagation functions were designed, using the Lotus Command Language.

Legend: D = DISTANCE = RADIUS
FS = FIELD-STRENGTH

1) $D_{NTSC\ F(50,50)}[FS_{NTSC}, EHAAT_{NTSC}]$ — $DISTANCE_{NTSC\ F(50,50)}$ as a function of FS & EHAAT

2) $FS_{ATV\ F(50,50)}[D_{ATV}, EHAAT_{ATV}]$ — $FS_{ATV\ F(50,50)}$ as a function of DISTANCE & EHAAT

3) $FS_{ATV\ F(50,10)}[D_{ATV}, EHAAT_{ATV}]$ — $FS_{ATV\ F(50,10)}$ as a function of DISTANCE & EHAAT

4) $D_{A>N\ F(50,10)}[FS_{ATV}, EHAAT_{ATV}]$ — $DISTANCE_{A>N\ F(50,10)}$ as a function of FS & EHAAT

5) $D_{N>A\ F(50,50)}[FS_{NTSC}, EHAAT_{NTSC}]$ — $DISTANCE_{N>A\ F(50,50)}$ as a function of FS & EHAAT

6) $D_{N>A\ F(50,10)}[FS_{NTSC}, EHAAT_{NTSC}]$ — $DISTANCE_{N>A\ F(50,10)}$ as a function of FS & EHAAT

7) $D_{A>A\ F(50,50)}[FS_{ATV}, EHAAT_{ATV}]$ — $DISTANCE_{A>A\ F(50,50)}$ as a function of FS & EHAAT

8) $D_{A>A\ F(50,10)}[FS_{ATV}, EHAAT_{ATV}]$ — $DISTANCE_{A>A\ F(50,10)}$ as a function of FS & EHAAT

9) $D_{N>N\ F(50,10)}[FS_{NTSC}, EHAAT_{NTSC}]$ — $DISTANCE_{N>N\ F(50,10)}$ as a function of FS & EHAAT

SPREADSHEET CALCULATION STEPS

This section will describe the sequential flow of the intermediate calculations required to output the co-channel separation distances.

1) $D_{NTSC\ F(50,50)}[FS_{NTSC}, EHAAT_{NTSC}]$

D is the radius (in km) of an NTSC coverage area, expressed as a function of the EHAAT (in m) of the transmitter antenna, and of the desired FS (in dBu/m for 1kW) transmitted power. The F(50,50) curves are used.

eg. For a station with an ERP of 30 dBK and an EHAAT of 300m, the Grade-B contour is represented as:

D{FS,EHAAT} = D{ (64-30), 300} using the F(50,50) curves = 69.5 km

2) $FS_{ATV\ F(50,50)}[D_{ATV}, EHAAT_{ATV}]$

FS is the field-strength (in dBu/m for 1kW) observed at a radius of D (in km) from a TX with a known EHAAT. The F(50,50) curves are used.

eg. $FS_{F(50,50)}\{D,EHAAT\} = FS_{F(50,50)}\{69.5, 300\} = 34$ dBu/m @1kW

3) $FS_{ATV\ F(50,10)}[D_{ATV}, EHAAT_{ATV}]$

FS is the field-strength (in dBu/m @1kW) observed at a radius of D (in km) from a TX with a known EHAAT. The F(50,10) curves are used.

eg. $FS_{F(50,10)}\{D,EHAAT\} = FS_{F(50,10)}\{69.5, 300\} = 40.3$ dBu/m @1kW

3a) Knowing $FS_{F(50,10)}$ and $FS_{F(50,50)}$, the following formula enables calculation of the FS at F(50,T) where T can be either 50 or vary from 90 to 99%.

$$FS_{F(50,T)} = FS_{F(50,50)} + k(T)*\{FS_{F(50,10)} - FS_{F(50,50)}\}/1.282$$

where k(T) is the Standard Variate of a normal distribution. Refer to Table 3 of the main report for the values of k(T).

eg. In the above case, where $FS_{F(50,10)}$ and $FS_{F(50,50)}$ are 40.3 and 34 respectively, and k(90) = -1.282,

$$FS_{F(50,T)} = 34 + (-1.282)*(40.3 - 34)/1.282 = 27.7 \text{ dBu/m@1kW}$$

3b) $Emin_{ATV} = 45.5 + 10*Log(BW/5) + [\ C/N - 16.5\ ]$

where: $Emin_{ATV}$ is the minimum ATV field-strength required to provide service for the given RX parameters.

45.5 dBu/m is the field-strength needed at 645 MHz for a receiver noise figure of 10 dB, antenna gain of 10dB, and cable loss of 4.9 dB, as can be found in Table 8 of the main report.

BW = Channel Bandwidth

C/N = Required Carrier-to-noise Ratio

eg. If the C/N = 16.5 dB and its BW = 5 MHz, then $Emin_{ATV}$ = 45.5 dBu/m

(GI system is being used here as the example system.)

3c) The ATV Power is calculated using the following formula:

$Power_{ATV} = (Emin_{ATV} - FS_{F(50,T)})$

eg. $Power_{ATV} = 45.5 - 27.7 = 17.8$ dBK

4) $D_{A>N\ F(50,10)}[FS_{ATV}, EHAAT_{ATV}]$

D is the distance (in km) from an ATV TX to the outer edge (Grade B contour) of an NTSC coverage area. D is expressed as a function of the EHAAT (in m) of the interfering ATV transmitter antenna, and of the FS (in dBu/m @1kW) of an interfering ATV station. The F(50,10) curves are used.

$FS = Emin_{NTSC} + F/B_{NTSC} - PR_{A>N} =$ 64 dBu + 6 dB - 30 dB = 40 dBu/m

Normalizing the FS for 1kW ATV power
$FS_{ATV} = FS - Power_{ATV} =$ 40 dBu/m - 17.8 dBK = 22.2 dBu/m@1kW

$D_{A>N\ F(50,10)}[FS_{ATV}, EHAAT_{ATV}] = 145.6$ km

4a) A>N Co-channel Separation Distance is calculated as follows:

$D_{A>N\ F(50,10)} + DISTANCE_{NTSC}$ * (% Coverage) = 145.6 + 69.5 * 100% = 215.1 km

5) $D_{N>A\ F(50,10)}[FS_{NTSC}, EHAAT_{NTSC}]$

D is the distance (in km) from an NTSC TX to the outer edge of an ATV coverage area. D is expressed as a function of the EHAAT (in m) of the interfering NTSC transmitter antenna, and of the FS (in dBu/m @1kW) of an interfering NTSC station. The F(50,10) curves are used.

$FS = Emin_{ATV} + F/B_{ATV} - PR_{N>A}$
= 45.5 dBu + 16 dB - 5 dB = 56.5 dBu/m

Normalizing the FS for 1kW NTSC power
$FS_{NTSC} = FS - Power_{NTSC} =$ 56.5 dBu/m - 30 dBK = 26.5 dBu/m@1kW

$D_{N>A\ F(50,10)}[FS_{NTSC}, EHAAT_{NTSC}] = 122.4$ km

6) $D_{N>A\ F(50,50)}[FS_{NTSC}, EHAAT_{NTSC}]$

D is the radius (in km) of an ATV coverage area, expressed as a function of the EHAAT (in m) of the transmitter antenna, and of the desired FS (in dBu/m for 1kW) transmitted power. The F(50,50) curves are used.

eg. For a contour having a FS = 56.5 dBu/m, and an EHAAT of 300m, interfered with by an NTSC station with an ERP of 30 dBK

$$D\{FS,EHAAT\} = D\{ (56.5\text{-}30), 300\} \text{ using the F(50,50) curves} = 84.9 \text{ km}$$

$D_{N>A\ F(50,50)}[FS_{NTSC}, EHAAT_{NTSC}] = 84.9$ km

6a) Knowing DISTANCE$\{FS_{F(50,10)}\}$ and DISTANCE$\{FS_{F(50,50)}\}$, the following formula enables calculation of the DISTANCE at F(50,T) where T can vary from 10 to 1%.

$$D\{FS_{F(50,T)}\} = D\{FS_{F(50,50)}\} + k(T)*[\ D\{FS_{F(50,10)}\} - D\{FS_{F(50,50)}\}\ ]/1.282$$

where k(T) is the Standard Variate of a normal distribution. Refer to Table 3 of the main report for the values of k(T).

eg. In the above case, where $D\{FS_{F(50,10)}\}$ and $D\{FS_{F(50,50)}\}$ are 116.1 and 82.4 km respectively, and k(10) = +1.282,

$$D\{FS_{F(50,T)}\} = 82.4 + (+1.282)*(116.1 - 82.4)/1.282 = 116.1 \text{ km}$$

6b) N>A Co-channel Separation Distance is calculated as follows:

$$D\{FS_{F(50,T)}\} + DISTANCE_{ATV} * (\%\ Coverage) = 122.4 + 69.5 * 100\% = 191.9 \text{ km}$$

7) $D_{A>A\ F(50,10)}[FS_{ATV}, EHAAT_{ATV}]$

D is the distance (in km) from an ATV TX to the outer edge of an adjacent ATV coverage area. D is expressed as a function of the EHAAT (in m) of the interfering ATV transmitter antenna, and of the FS (in dBu/m @1kW) of an interfering ATV station. The F(50,10) curves are used.

The FS = $Emin_{ATV} + F/B_{ATV} - PR_{A>A}$
= 45.5 dBu + 16 dB - 16 dB = 45.5 dBu/m

Normalizing the FS for 1kW ATV power
$FS_{ATV} = FS - Power_{ATV}$ = 45.5 dBu/m - 17.8 dBK = 27.7 dBu/m@1kW

$D_{A>A\ F(50,10)}[FS_{ATV}, EHAAT_{ATV}] = 116.1$ km

8) $D_{A>A\ F(50,50)}[FS_{ATV}, EHAAT_{ATV}]$

D is the radius (in km) of an ATV coverage area, expressed as a function of the EHAAT (in m) of the transmitter antenna, and of the desired FS (in dBu/m for 1kW) transmitted power. The F(50,50) curves are used.

eg. For a contour having a FS = 45.5 dBu/m, and an EHAAT of 300m, interfered with by an adjacent ATV station with an ERP of 17.8 dBK

D{FS,EHAAT} = D{ (45.5-17.8), 300} using the F(50,50) curves = 82.4 km

$D_{A>A\ F(50,50)}[FS_{ATV}, EHAAT_{ATV}]$ = 82.4 km

8a) Knowing DISTANCE$\{FS_{F(50,10)}\}$ and DISTANCE$\{FS_{F(50,50)}\}$, the following formula enables calculation of the DISTANCE at F(50,T) where T can vary from 10 to 1%.

$D\{FS_{F(50,T)}\} = D\{FS_{F(50,50)}\} + k(T)*[D\{FS_{F(50,10)}\} - D\{FS_{F(50,50)}\}]/1.282$

where k(T) is the Standard Variate of a normal distribution. Refer to Table 3 of the main report for the values of k(T).

eg. In the above case, where $D\{FS_{F(50,10)}\}$ and $D\{FS_{F(50,50)}\}$ are 122.4 and 84.9 km respectively, and k(10) = +1.282,

$D\{FS_{F(50,T)}\}$ = 84.9 + (+1.282)*(122.4 - 84.9)/1.282 = 122.4 km

8b) A>A Co-channel Separation Distance is calculated as follows:

$D\{FS_{F(50,T)}\}$ + $DISTANCE_{ATV}$ * (% Coverage) = 116.1 + 69.5 * 100% = 185.6 km

9) $D_{N>N\ F(50,10)}[FS_{NTSC}, EHAAT_{NTSC}]$

D is the distance (in km) from an NTSC TX to the outer edge of an adjacent NTSC coverage area. D is expressed as a function of the EHAAT (in m) of the interfering NTSC transmitter antenna, and of the FS (in dBu/m @1kW) of an interfering NTSC station. The F(50,10) curves are used.

The FS = $Emin_{NTSC}$ + F/B_{NTSC} - $PR_{N>N}$
= 64 dBu + 6 dB - 28 dB = 42 dBu/m

Normalizing the FS for 1kW NTSC TX power
FS_{NTSC} = FS - $Power_{NTSC}$ = 42 dBu/m - 30 dBK = 12 dBu/m for 1kW

$D_{N>N\ F(50,10)}[FS_{NTSC}, EHAAT_{NTSC}]$ = 202.9

9a) N>N Co-channel Separation Distance is calculated as follows:

$D_{N>N\ F(50,10)}$ + $DISTANCE_{NTSC}$ * (% Coverage) = 202.9 + 69.5 * 100% = 272.4 km

EXAMPLES OF SPREADSHEET OUTPUT

ZENITH / AT&T (4VSB) with RECEIVER NOISE FIGURE = 10 dB

```
      A    B    C    D     E     F     G     H     I     J      K      L
 1    CRC ATV-NTSC Co-Channel Separation                    ATV
 2    ~~~~~~~~~(Freq=645MHz)~~~~~~~~~~~~~   Bandwidth (MHz)  ~~~          6
 3             ~~~~~~~~~~~~~            |  C/N (dB)                   16.0
 4                   NTSC               |  Receiver NF=1-15 (dB)        10
 5    ERP (dBK)     ~~~~~~        30    |  Emin (dBu/m)               45.8
 6    EHAAT (m)                  300    |  F(50,T) T=50,90-99 (%)       90
 7    Emin (dBu/m)                64    |  Radius (km)               69.48
 8                                      |  EHAAT (m)                   300
 9    F(50,50) Radius (km)     69.48    |  ERP (dBK)                  18.1
10    ----------------------------------|----------------------------------
11    RX antenna F/B ratio (dB)     6   |  RX antenna F/B ratio (dB)    16
12    Interference into NTSC   F(50,10) |  Interference into ATV
13                                      |       F(50,T) T=1-10 (%)      10
14    % Cov. Radius protected     100   |  % Cov Radius protected      100
15    =====================================================================
16        Protection ratios (dB)          Co-channel separation distance (km)
17                    Desired                                  Desired
18                  NTSC   ATV                               NTSC   ATV
19    Undesired NTSC  28     0        HELP    Undesired NTSC  272.4 166.7
20              ATV   30    16       Pg Dn              ATV   216.6 185.6
```

ZENITH / AT&T (4VSB) with Optimum RECEIVER NOISE FIGURE = 5.3 dB

```
      A    B    C    D     E     F     G     H     I     J      K      L
 1    CRC ATV-NTSC Co-Channel Separation                    ATV
 2    ~~~~~~~~~(Freq=645MHz)~~~~~~~~~~~~~   Bandwidth (MHz)  ~~~          6
 3             ~~~~~~~~~~~~~            |  C/N (dB)                   16.0
 4                   NTSC               |  Receiver NF=1-15 (dB)       5.3
 5    ERP (dBK)     ~~~~~~        30    |  Emin (dBu/m)               40.8
 6    EHAAT (m)                  300    |  F(50,T) T=50,90-99 (%)       90
 7    Emin (dBu/m)                64    |  Radius (km)               69.48
 8                                      |  EHAAT (m)                   300
 9    F(50,50) Radius (km)     69.48    |  ERP (dBK)                  13.1
10    ----------------------------------|----------------------------------
11    RX antenna F/B ratio (dB)     6   |  RX antenna F/B ratio (dB)    16
12    Interference into NTSC   F(50,10) |  Interference into ATV
13                                      |       F(50,T) T=1-10 (%)      10
14    % Cov. Radius protected     100   |  % Cov Radius protected      100
15    =====================================================================
16        Protection ratios (dB)          Co-channel separation distance (km)
17                    Desired                                  Desired
18                  NTSC   ATV                               NTSC   ATV
19    Undesired NTSC  28     0        HELP    Undesired NTSC  272.4 190.2
20              ATV   30    16       Pg Dn              ATV   189.9 185.6
```

ATRC (32 QAM) with RECEIVER NOISE FIGURE = 10 dB

```
  A     B     C     D     E     F     G  ·  H     I     J     K     L
CRC ATV-NTSC Co-Channel Separation                       ATV
~~~~~~~~~(Freq=645MHz)~~~~~~~~~~~~~    Bandwidth (MHz)   ~~~              6
          ~~~~~~~~~~~~~~             | C/N (dB)                        16.1
                NTSC                 | Receiver NF=1-15 (dB)             10
ERP (dBK)       ~~~~~~        30     | Emin (dBu/m)                    45.9
EHAAT (m)                    300     | F(50,T) T=50,90-99 (%)            90
Emin (dBu/m)                  64     | Radius (km)                    69.48
                                     | EHAAT (m)                        300
F(50,50) Radius (km)       69.48     | ERP (dBK)                       18.2
-------------------------------------|-----------------------------------
RX antenna F/B ratio (dB)      6     | RX antenna F/B ratio (dB)         16
Interference into NTSC   F(50,10)    | Interference into ATV
                                     |      F(50,T) T=1-10 (%)           10
% Cov. Radius protected      100     | % Cov Radius protected           100
=========================================================================
    Protection ratios (dB)             Co-channel separation distance (km)
                 Desired                                       Desired
               NTSC   ATV                                    NTSC   ATV
Undesired NTSC  28     -2        HELP     Undesired NTSC    272.4 158.8
          ATV   30     16       Pg Dn               ATV     217.2 185.6
```

ATRC (32 QAM) with Optimum RECEIVER NOISE FIGURE = 4.3 dB

```
  A     B     C     D     E     F     G     H     I     J     K     L
CRC ATV-NTSC Co-Channel Separation                       ATV
~~~~~~~~~(Freq=645MHz)~~~~~~~~~~~~~    Bandwidth (MHz)   ~~~              6
          ~~~~~~~~~~~~~~             | C/N (dB)                        16.1
                NTSC                 | Receiver NF=1-15 (dB)            4.3
ERP (dBK)       ~~~~~~        30     | Emin (dBu/m)                    39.8
EHAAT (m)                    300     | F(50,T) T=50,90-99 (%)            90
Emin (dBu/m)                  64     | Radius (km)                    69.48
                                     | EHAAT (m)                        300
F(50,50) Radius (km)       69.48     | ERP (dBK)                       12.1
-------------------------------------|-----------------------------------
RX antenna F/B ratio (dB)      6     | RX antenna F/B ratio (dB)         16
Interference into NTSC   F(50,10)    | Interference into ATV
                                     |      F(50,T) T=1-10 (%)           10
% Cov. Radius protected      100     | % Cov Radius protected           100
=========================================================================
    Protection ratios (dB)             Co-channel separation distance (km)
                 Desired                                       Desired
               NTSC   ATV                                    NTSC   ATV
Undesired NTSC  28     -2        HELP     Undesired NTSC    272.4 185.0
          ATV   30     16       Pg Dn               ATV     184.7 185.6
```

GI (32 QAM) with RECEIVER NOISE FIGURE = 10 dB

```
A    B    C    D    E    F    G    H    I    J    K    L
CRC ATV-NTSC Co-Channel Separation                      ATV
~~~~~~~~~(Freq=645MHz)~~~~~~~~~~~~~  Bandwidth (MHz)  ~~~       5
           ~~~~~~~~~~~~~          |  C/N (dB)                16.5
                NTSC              |  Receiver NF=1-15 (dB)     10
ERP (dBK)      ~~~~~~        30   |  Emin (dBu/m)            45.5
EHAAT (m)                   300   |  F(50,T) T=50,90-99 (%)    90
Emin (dBu/m)                 64   |  Radius (km)            69.48
                                  |  EHAAT (m)                300
F(50,50) Radius (km)      69.48   |  ERP (dBK)               17.8
----------------------------------|-----------------------------------
RX antenna F/B ratio (dB)     6   |  RX antenna F/B ratio (dB)     16
Interference into NTSC   F(50,10) |  Interference into ATV
                                  |      F(50,T) T=1-10 (%)        10
% Cov. Radius protected     100   |  % Cov Radius protected       100
======================================================================
    Protection ratios (dB)          Co-channel separation distance (km)
             Desired                                         Desired
            NTSC   ATV                                    NTSC   ATV
Undesired NTSC  28    5        HELP     Undesired NTSC   272.4 191.9
          ATV   30   16       Pg Dn               ATV    215.1 185.6
```

GI (32 QAM) with Optimum RECEIVER NOISE FIGURE = 7.8 dB

```
A    B    C    D    E    F    G    H    I    J    K    L
CRC ATV-NTSC Co-Channel Separation                      ATV
~~~~~~~~~(Freq=645MHz)~~~~~~~~~~~~~  Bandwidth (MHz)  ~~~       5
           ~~~~~~~~~~~~~          |  C/N (dB)                16.5
                NTSC              |  Receiver NF=1-15 (dB)    7.8
ERP (dBK)      ~~~~~~        30   |  Emin (dBu/m)            43.3
EHAAT (m)                   300   |  F(50,T) T=50,90-99 (%)    90
Emin (dBu/m)                 64   |  Radius (km)            69.48
                                  |  EHAAT (m)                300
F(50,50) Radius (km)      69.48   |  ERP (dBK)               15.6
----------------------------------|-----------------------------------
RX antenna F/B ratio (dB)     6   |  RX antenna F/B ratio (dB)     16
Interference into NTSC   F(50,10) |  Interference into ATV
                                  |      F(50,T) T=1-10 (%)        10
% Cov. Radius protected     100   |  % Cov Radius protected       100
======================================================================
    Protection ratios (dB)          Co-channel separation distance (km)
             Desired                                         Desired
            NTSC   ATV                                    NTSC   ATV
Undesired NTSC  28    5        HELP     Undesired NTSC   272.4 203.5
          ATV   30   16       Pg Dn               ATV    202.7 185.6
```

MIT / GI (32 QAM) with RECEIVER NOISE FIGURE = 10 dB

```
     A    B    C    D    E    F    G    H     I     J    K    L
1    CRC ATV-NTSC Co-Channel Separation              ATV
2    ~~~~~~~~~(Freq=645MHz)~~~~~~~~~~~~~   Bandwidth (MHz)  ~~~        6
3             ~~~~~~~~~~~~~~          |  C/N (dB)                  15.7
4                  NTSC               |  Receiver NF=1-15 (dB)       10
5    ERP (dBK)      ~~~~~~     30     |  Emin (dBu/m)              45.5
6    EHAAT (m)                300     |  F(50,T) T=50,90-99 (%)      90
7    Emin (dBu/m)              64     |  Radius (km)              69.48
8                                     |  EHAAT (m)                  300
9    F(50,50) Radius (km)   69.48     |  ERP (dBK)                 17.8
10   ---------------------------------|----------------------------------
11   RX antenna F/B ratio (dB)    6   |  RX antenna F/B ratio (dB)   16
12   Interference into NTSC F(50,10)  |  Interference into ATV
13                                    |       F(50,T) T=1-10 (%)     10
14   % Cov. Radius protected    100   |  % Cov Radius protected     100
15   ====================================================================
16       Protection ratios (dB)          Co-channel separation distance (km)
17                    Desired                                  Desired
18                 NTSC   ATV                               NTSC   ATV
19   Undesired NTSC  28     6       HELP     Undesired NTSC  272.4 197.1
20             ATV   30  15.2      Pg Dn               ATV   215.1 181.7
```

MIT / GI (32 QAM) with Optimum RECEIVER NOISE FIGURE = 8.4 dB

```
     A    B    C    D    E    F    G    H     I     J    K    L
1    CRC ATV-NTSC Co-Channel Separation              ATV
2    ~~~~~~~~~(Freq=645MHz)~~~~~~~~~~~~~   Bandwidth (MHz)  ~~~        6
3             ~~~~~~~~~~~~~~          |  C/N (dB)                  15.7
4                  NTSC               |  Receiver NF=1-15 (dB)      8.4
5    ERP (dBK)      ~~~~~~     30     |  Emin (dBu/m)              43.9
6    EHAAT (m)                300     |  F(50,T) T=50,90-99 (%)      90
7    Emin (dBu/m)              64     |  Radius (km)              69.48
8                                     |  EHAAT (m)                  300
9    F(50,50) Radius (km)   69.48     |  ERP (dBK)                 16.1
10   ---------------------------------|----------------------------------
11   RX antenna F/B ratio (dB)    6   |  RX antenna F/B ratio (dB)   16
12   Interference into NTSC F(50,10)  |  Interference into ATV
13                                    |       F(50,T) T=1-10 (%)     10
14   % Cov. Radius protected    100   |  % Cov Radius protected     100
15   ====================================================================
16       Protection ratios (dB)          Co-channel separation distance (km)
17                    Desired                                  Desired
18                 NTSC   ATV                               NTSC   ATV
19   Undesired NTSC  28     6       HELP     Undesired NTSC  272.4 205.7
20             ATV   30  15.2      Pg Dn               ATV   206.1 181.7
```