Interference to DTTV Reception by First Adjacent Channels

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Abstract—**Planning for digital terrestrial television (DTTV) service in a crowded spectrum requires that power limits be placed on all adjacent channels, and in particular on first adjacent channels. Realistic power limits based on intermodulation products generated at the receiver by the desired and undesired signals are proposed. The proposed limits are a function of the fundamental power in the desired and undesired channels and the receiver's 3rd order Intercept Point (IP_3). The analysis shows that in many markets present Desired/Undesired (D/U) ratios underestimate the expected interference from strong signals, and that the receiver's IP_3 should be at least 16 dBm for the dynamic range expected in the US. Additional improvement can be attained by minimizing the sideband splatter generated by the transmitter of the first adjacent channel and by designing a "smart" front-end receiver.**

Index Terms—**DTTV, adjacent channel interference, intermodulation, cross-modulation, 3rd order intercept, dynamic range, desired to undesired ratios.**

I. INTRODUCTION

The allocation of channels for analog television in the US was based on strict rules that resulted in minimal interference among TV stations. Taboo channels and minimum separation distances were codified into the Federal Communications Commission (FCC) rules and regulations that protected television stations from inter-market and intra-market interference by other stations. These measures have worked well. However, the UHF television spectrum was left with unused bandwidth.

Prior to DTTV, intermodulation (IM) products generated at the receiver by adjacent channels were nonexistent, nor was there sideband splatter generated by the transmitter of the first adjacent channels because the N±1 channels were taboo channels. Further, the dynamic range and the effective noise figure of the receiver are far less critical to for analog television reception than for DTTV reception.

With the introduction of DTTV, the number of channels assigned to each market doubled even while the available spectrum was reduced. The FCC packed the spectrum because it believed that in the DTTV world, "taboo" channels would not be required. Spectrum packing was thought possible because the underlying tests for the D/U ratios, now codified in the FCC rules and regulations, were not based real-world conditions. Even the dynamic range of –84 to 0 dBm of a single channel at the input to the receiver, as implied by the FCC's Table of Allotments and the FCC's planning factors, were inexplicably not part of the tests.

For example, IM interference by strong desired and undesired signals and the sideband splatter generated by the transmitter of adjacent channel were ignored. The tests were conducted with only one interferor even though the channel allocation table shows that in many markets both upper and lower adjacent channels have been assigned. A highly directional rooftop was assumed within the station's protected service area. One hypothetical pattern for all channels within each band was used to predict interference even though that pattern may have no resemblance to the actual pattern used by the interferor. Adjacent channels were assumed collocated on one transmitting antenna, but collocation was not mandated. The last assumption cannot apply to on-channel repeaters or for distributed transmitters in markets where the distributed channel is adjacent to another channel.

For now the population of DTTV receivers is relatively insignificant and many stations are transmitting their digital signal at a lower than licensed power and for limited periods of time. As more stations raise their power to the maximum allowed and as more receivers penetrate the consumer market, the interference to reception will become more pervasive.

There are several ways in which the expected interference could be reduced to an acceptable level: (a) the maximum allowable transmitter splatter into adjacent channels may be reduced, (b) the adjacent channels may be collocated. (c) the transmitting antenna's pattern may be shaped, and (d) "smart" receivers with controlled antenna pattern and front-end filter with shaped bandpass may be able to reject undesired interference [9]. In some markets, permitting on-channel repeaters may have to be subject to DTTV taboo channel restriction and/or terrain shielding. Finally, the receiver system tradeoffs should be understood and selected to meet reasonable balance among interference rejection, front-end overloading and sensitivity.

DTTV service planning requires a reliable propagation algorithm, adequate signal to noise ratio (SNR) and assessment of the interference to the desired channel from other channels. Previously, we dealt with the propagation algorithm [1] and with the SNR [2] issues. In this paper we address the allowable interference level as a function of the transmitted power and the receiver design.

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II. TYPES OF INTERFERENCE

Figure 1 shows the various types of potential interference to a desired DTTV channel, each 6MHz wide, from adjacent channels within a passband of 18 - 78 MHz. Present consumer-grade receivers may have a passband filter that is wider than 78 MHz. Central to the allowable level of interference without reception failure are the allowable splatter at the transmitter, the dynamic range of the receiver and the added noises internal and external to the receiver.

The most pervasive interference is Type 1. It is a combination of transmitter's sideband splatter, the 3rd order IM products (IM_3) and the cross-modulation[*] (XM) in-channel and by the first (N±1) adjacent channel, analog or digital. The transmitter's sideband splatter contains 3rd and 5th order IM products generated mostly by the non-linearity of the power amplifier (PA). The IM_3 spectrum is three channels wide centered at the middle of the channel and extends throughout the N±1 adjacent channels. The sideband splatter of the undesired channel transmitter appears as co-channel interference to the desired channel.

The least important interference is Type 2. It constitutes the 5th order IM products generated at the transmitter of the second (N±2) adjacent channel. Type 2 also appears to the desired channel as co-channel interference.

The types of interference least recognized are Types 3-5. These types produce 3rd order IM products inside the desired channel when certain pairs of channels are mixed within the nonlinear portion of the dynamic range at the front end of the receiver.

For example, consider the interference situation in Miami, Denver and Washington DC shown in Table I. These are by no means isolated cases. In Miami, eleven out of twelve stations are subject to Type 1 interference. Five out of the eleven are subject to Type 1 interference from more than one adjacent channel as well as from Type 3-5 interference. Since the 11 channels are not collocated, the potential for additional IM and XM interference from first adjacent channels into the desired channel is also high. Within the first few miles of the transmitter the power level of some of the channels is sufficiently high to generate high levels of IM products and XM within the channel even without adjacent channels present. The growth of in-channel IM and XM products with increased power of the fundamental may lead to an overload of the receiver's front end, eventually leading to reception failure.

III. THE DYNAMIC RANGE

Ideally, the receiver should be able to demodulate the desired signal, whether "weak" or "strong", without additionally degrading the SNR available at the input to the receiver. Degradations to the dynamic range could be linear or nonlinear. The linear degradation is independent of the signal level and is primarily due to impedance mismatch between the antenna and the front end. The nonlinear degradation depends on the input power level, sometimes the power sum of several channels, and is manifested as interference by intermodulation products and cross-modulation.

The "weak" DTTV signal level is given by:

$$P_{MIN}\,(dBm) = -106.2 + ENF + SNR_T \qquad (1)$$

where:
ENF = effective noise figure in dB
SNR_T = threshold SNR in dB

For DTTV and 8-VSB modulation with SNR_T= 15.2 dB and ENF = 11 dB, P_{MIN} = -84 dBm.

For n receivers connected through a cable and a lossless power splitter to an antenna with LNA at its terminals, the effective noise figure at the antenna terminals is [1], [11]:

$$ENF = K_{LNA}F_{LNA} + n\frac{K_R F_R - \eta \;\; / n}{\eta \; G_{LNA}} \qquad (2)$$

Where:
η = downlead cable efficiency
G_{LNA} = gain ratio of the LNA
F_R = receiver noise figure
F_{LNA} = noise figure ratio of the LNA
K_{LNA} = Impedance mismatch factor between the LNA and the antenna. K_{LNA} = 1 for perfect match.
K_R = Impedance mismatch factor between the source and the receiver front-end. K_R = 1 for perfect match.

Thus, if the gain of the LNA is sufficiently high, the ENF is dominated by noise figure of the LNA and successive stages add little to the ENF.

The "strong" signal level depends on the radiated power and the antenna height of the desired channel. For DTTV with allowable ERP (Effective Radiated Power) of 1,000 kW at UHF channels, the maximum signal is estimated at –10 dBm. For NTSC with allowable ERP of 5,000 kW at UHF channels, the maximum signal is estimated at –3 dBm. For NTSC with allowable ERP of

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[*] The generation of IM products and XM follows the same cubic law with respect to the power of the fundamental signal. Whereas IM generates new spectral lines outside the desired spectral lines ("regrowth"), XM does not generate new spectral lines. The effect of XM is to modulate existing spectral lines. More details later in this paper.

100 kW at VHF channels, the maximum signal is estimated at 0 dBm.

Therefore, the linear dynamic range of a television receiver designed for analog and digital channels and in compliance with the FCC planning factors would ideally extend from -84 dBm to 0 dBm. That should have been the range when the D/U ratios adopted by the FCC were determined experimentally at the Advanced Technology Test Center (ATTC).

IV. EARLY EXPERIMENTS

Table II shows the first adjacent channel D/U ratios at the "threshold of reception" documented by the ATTC tests [3]. The desired channel is N and the undesired channel is N±1. The D/U adopted by the FCC in 1997 were based on a desired signal level of –68dBm. In 1998, following additional tests [4] that incorporated the adjacent channel splatter by the transmitter, the D/U ratio of the undesired N-1 channel and the desired N channel was raised from –42 to –28 dB and the D/U ratio of the undesired N+1 channel and the desired N channel from –43 dB to –26 dB. Even at that stage there was lack of recognition that the difference in the D/U between that for N+1 and that for N-1 was an experimental error, not a fundamental difference. Also not recognized at that stage was the importance of strong and multiple signals within the expected dynamic range to the determination of realistic D/U ratios.

These low D/U ratios, which were based on a –68 dBm desired signal and a single –26 dBm undesired signal and without man-made noise present, made it possible to allocate adjacent DTTV channels and ignore the issue of "taboo" channels. Even with these low ratios it was necessary to collocate the adjacent channels on the same transmitting antenna and to use a high-gain directional receive antenna to keep (theoretically) the expected interference from non-collocated channels to an acceptable level.

V. THIRD ORDER DISTORTION AT THE RECEIVER

Of all the nonlinear degradations, the XM and IM_3 are of greatest concern because they always fall within the passband of the front filter. Figure 2 shows the bandwidth interference resulting when a *single* strong signal of a 6 MHz wide DTTV channel is passed through a nonlinear device such as a mixer or an LNA. Note that while the IM_3 interference spread over three channels, the XM interference is confined within the channel. Additional XM splatter into the desired channel may result if an adjacent channel is present and is cross modulated by another strong DTTV channel. The latter can be eliminated if front-end passband is limited to three channels.

Central to the analysis of the interference power generation is the IP_3 of each nonlinear device in the path of the desired signal. The IP_3 is defined as the input power at which a nonlinear device generates undesired IM_3 with power level equal to that of the desired signal. The experimental determination of IP_3, and its relationship to the level of IM_3 generated by a given input power is detailed in Appendix A.

For cascaded devices, it is useful to derive an expression of the system's IP_3, which is representative of the cascaded devices. Such an expression is akin to that derived for the noise figure of cascaded devices.

Figure 3 shows an example of a DTTV receiver front end made of LNA, downlead cable, mixer, and a bandpass filter. It can be shown that, referred to the antenna terminals, the system IP_3 of the cascaded devices shown in Figure 3 is:

$$\frac{1}{IP_3} = \frac{1}{IP_{LNA}} + \frac{G_{LNA}}{IP_F S^{3/2} L \eta} \qquad (3)$$

where:
IP_{LNA} = IP_3 of the LNA
IP_F = IP_3 of the mixer/IF block
η = Insertion loss of the downlead cable
G_{LNA} = gain ratio of the LNA
$S^{3/2}$ = Filter selectivity of the undesired adjacent channel
L = Filter insertion loss

Without LNA G=1 and $1/IP_{LNA} = 0$. In that case, the effective IP_3 referred to the input of the receiver and expressed in dBm is:

$$IP_3(dBm) = IP_F(dBm) + \frac{3}{2}\left|S(dB)\right| + \left|L(dB)\right| \quad (3a)$$

Therefore the IP_3 improves with increased selectivity and inserted loss at the front end. Higher IP_3 results in lower IM_3 and XM interference.

Although equation (3) is frequency-dependent, we shall assume average parameters over 18 MHz. It is clear that an increase in the gain of the LNA will result in a higher level of IM_3 whereas an increase in attenuation and selectivity will result in a reduced level of IM_3. Comparing equation (2) and (3) shows that an increase in gain of the LNA improves the system's noise figure and degrades the system IP_3. Therefore, for optimum receiver operation, a compromise between the level of undesired interference generated at the receiver and the receiver's noise figure is required.

The traditional analysis of two-tone interference is outlined in Appendix A. Because the traditional approach is based on two discrete frequencies, it is not of much help in the analysis of wideband signals such as wideband digital signals. For a wideband signal, as long as the output power and SNR are well below their 1 dBm compression point, the spectral power density of the third order distortion referring to the input is given by [5], [6]:

$$S(f)=\left\{\begin{array}{l}\frac{1}{2B}\left[6P_0^2 10^{-.1IP_3}+9P_0^3 10^{-.2IP_3}\right]\\ +\frac{3}{4B^3}P_0^3 10^{-.2IP_3}\left[3B^2-\left|f-f_0\right|^2\right]\end{array}\right\}(4)$$

$$for\ \left|f-f_0\right|\le B$$

and

$$S(f)=\frac{3}{8B^3}P_0^3 10^{-.2IP_3}\left[3B-\left|f-f_0\right|\right]^2\ (5)$$

$$for\ B<\left|f-f_0\right|\le 3B$$

Equation (4) is the output power spectral density (in Watts/Hertz) within a channel bandwidth of 2B and equation (5) is the spectral density of the splatter within the first adjacent channels. In (4) and (5), f_0 is the center frequency of the DTTV channel, P_0 is input power of the fundamental signal and IP_3 is the 3rd order intercept. The first two terms of equation (4) represent the in-channel spectral density of the XM component, which is constant, and the third term represents the in-channel spectral density of IM_3 component, which is dependent on the frequency shift relative to f_0. Equation (5) represents the IM_3 splatter into the first adjacent channels, which is dependent on the frequency shift relative to f_0.

It takes two input spectral lines to produce two new IM_3 spectral lines, one above and one below the input spectral lines. It takes only one *modulated* input spectral line to cross-modulate another input spectral line. Thus, the in-channel XM represents a signal-correlated cochannel perturbation that does not create in new spectral lines. A more complete description of XM and IM distortion is given in [6], [7] and [8].

The total power between any two frequencies, f_a and f_b, is:

$$P_{ab}\left(f_a,f_b\right)=\int_{f_a}^{f_b}S(f)df\quad 0<f_a<f_b\ (6)$$

Integrating equation (4) yields:

$$P_{ab}(f_a,f_b)=$$

$$\left\{\begin{array}{l}\frac{\left|f_b-f_a\right|}{2B}\left[6P_0^2 10^{-.1IP_3}+9P_0^3 10^{-.2IP_3}\right]\\ +\frac{3}{4B^3}P_0^3 10^{-.2IP_3}\left[3B^2\left(f_b-f_a\right)+\frac{1}{3}\left(\left|f_a-f_0\right|^3-\left|f_b-f_0\right|^3\right)\right]\end{array}\right\}(7)$$

$$for\ \left|f-f_0\right|\le B$$

When $f_a = f_1$ and $f_b = f_2$ (see Fig. 2), the total XM+IM_3 power within the channel is:

$$P_{IM+XM}=6P_0^2 10^{-.1IP_3}+13.5P_0^3 10^{-.2IP_3}\ (8)$$

For the splatter into the first adjacent channel, integration of (5) yields:

$$IM_3(f_a,f_b)=$$

$$\frac{1}{8B^3}P_0^3 10^{-.2IP_3}\left[\left(3B-\left|f_a-f_0\right|\right)^3-\left(3B-\left|f_b-f_0\right|\right)^3\right](9)$$

$$for\ B<\left|f-f_0\right|\le 3B$$

When $f_a = f_1$ and $f_b = f_3$ or f_4 (see Fig. 2), the total splattered IM_3 power in the first adjacent channel is:

$$IM_3=P_0^3 10^{-.2IP_3}$$

$$IM_3(dBm)=3P_0(dBm)-2IP_3(dBm)\qquad(10)$$

Equation (10) corresponds to the traditional formula based on two-tone analysis.

It should be noted that in the case of digital modulation the peak envelope power over the average power P_0 would magnify the IM_3 level to some extent. In applying equation (4) to (10) the system's IP_3 should be used. For the system shown in Fig.3, the IP_3 is given in equation (3). When comparing the calculated power spectral density with that observed on a spectrum analyzer, the analyzer resolution bandwidth should be taken into account.

Figure 4 shows the calculated spectral density of the 3rd order distortion relative to that of a fundamental with total power = -25.5 dBm and a system IP_3 = 3.5 dBm. Note that the Adjacent Channel Power Ratio (ACPR) is 58 dB below the fundamental.

In the absence of a plot showing the power of the intermodulation products generated by the demodulator used in the ATTC tests, it is instructive to estimate the IP_3 of the receiver used in the ATTC tests. From Table II,

D = –68 dBm and U = –25.5 dBm.

At the threshold of visibility (TOV),

$SNR_{TOV} \approx 15.5$ dB (.3 over threshold)

Assuming the noise floor was well below this level[†],

$IM_3 = D - SNR_{TOV} = 68 - 15.5 = -83.5$ dBm

From equation (10),

$IP_3 = .5(3U – IM_3) = 3.5$ dBm.

The ACPR of the Undesired is

ACPR = IM_3- U = –58 dB.

[†] The ATTC receiver was tested at low power levels in a perfectly linear test setup and without sideband splatter by the adjacent channel. Thus only IM_3 is interference is assumed to be of significance.

Comparing the result of the ATTC test with Figure 4 shows the estimated IM and XM spectra in the Desired and Undesired channels when the test was run at a Desired level of –68 dBm and the Undesired level at –25.5 dBm.

It should be noted that the estimated IP_3 of the receiver used in the ATTC tests might not be accurate. Results of tests that were run at higher levels of D and U yield higher levels of IP_3. However, the low input levels, as long as they are well above the noise floor, the more likely the slope of IM_3, as shown in Fig. A1, to be constant [7]. In any case, the results and conclusions of this paper are independent of the exact IP_3 of the demodulator used in the tests at the ATTC.

Figures 5 and 6 show, respectively, the ACPR and in-channel SNR as a function of the fundamental input power for IP_3 between 2 and 16 dBm based on equation (7) for the in-channel SNR and equation (9) for the ACPR. Note from Fig. 6 that the higher the input power, the higher the IP_3 required to maintain SNR above the point of reception failure. In particular, if the receiver is expected to perform well with multiple strong signals, its IP_3 should be at least 16 dBm.

With current technology the passband of the front-end filter is more than one channel wide and undesired adjacent channel(s), possibly stronger than the desired channel, would enter the active stages of the receiver. The Automatic Gain Control (AGC) of the receiver would then respond to the weak desired channel and the increased gain would apply to both channels. The stronger undesired channels would then generate splatter into the desired channel, which could result in reception failure. This additional splatter, generated at the receiver, is in addition to the total sideband splatter (IM_3 + IM_5) generated by the transmitters of the same adjacent channels. Appendix B provides the allowable sideband splatter by the FCC for DTTV and NTSC channels.

In addition to the interference by IM and XM products in the desired and/or by the adjacent channel, 3rd order distortion could additionally reduce the conversion gain of the desired channel. This effect, sometimes called *desensitization* or *blocking*, occurs when a very strong channel, not necessarily adjacent, is present at the input to the front-end of the receiver. In some communities, the power level at the input to the receiver by multiple stations can reach 0 dBm. In fact, even a single station with Effective Radiated Power (ERP) of 1 MW can deliver a signal level close to 0 dBm to a receiver within a few miles of the transmitter.

For example, consider the situation in Dallas, TX. Table III lists the UHF stations transmitting from Cedar Hill in Dallas and serving the Dallas-Fort Worth market.

From Table III, the total average ERP would be 48,117 kW with peak ERP 17 times (12 dB) higher. At 10 miles from Cedar Hills, the estimated[‡] power at the receiver's input is 0 dBm if the receive antenna is a simple dipole and +9 dBm if the gain is 10 dB higher. At such levels, the AGC is expected to desensitize the front end of the receiver, possibly to the point where the signals of the lower power stations cannot be decoded. At the same time, the higher power stations could result in blocking and/or in excessive IM and possibly in XM interference to the desired channel.

VI. SPLATTER FROM FIRST ADJACENT CHANNELS MODULATED BY ANOTHER CHANNEL

Another by-product of the non-linearity of active devices is XM of a strong undesired adjacent channel by another channel. The new spectrum around the newly modulated adjacent channel is twice the bandwidth of the modulating channel. Part of the newly created spectrum overlaps the desired channel, thereby degrading the SNR of the desired channel. This newly created spectrum is illustrated in Figure 7 wherein interferor DTTV channel amplitude modulates an adjacent NTSC channel, creating XM spectrum that overlaps that of the desired DTTV channel. Note that in the latter case, the carrier of the modulated adjacent channel must not be offset more than 3B/2 for the XM noise to fall within the desired DTTV channel.

A simple expression for the XM power has been developed for CDMA channels whose spectrum is similar to that of digital television. The corrected[*] cross-modulation factor for a box-shaped spectrum is [8]:

$$C = .5\left(\frac{3}{2} - \frac{\Delta F}{B}\right)^2 \delta \quad (11)$$

where:

δ = Nyquist filter correction factor for 8-VSB modulation, $10\text{Log}\delta \approx -2$ dB.

B = Bandwidth of the modulating channel.

ΔF = Frequency shift of the adjacent channel relative to the center frequency of the desired channel.

For adjacent DTTV channel, C=-8 dB. For upper adjacent NTSC channel, C=-6 dB and for lower adjacent NTSC channel, C=-12 dB.

Since XM is 3rd order non-linear distortion, the average XM power can be estimated from [8]:

$$XM\,(dBm) = 2(P_I - IP_3) + P_{AC} + C \quad (12)$$

where:

All power levels are at the input to the system.

[‡] Assuming free-space attenuation.

[*] There appears to be a factor of 2 error in the cited reference.

P_I = Average power in dBm of the interferor modulating the adjacent channel.
P_{AC} = Average power in dBm of the channel being modulated by the interferor.
IP_3 = System's 3rd order intercept point in dBm.
C = Cross-modulation factor in dB.

Note that equation (12) does not include a correction factor for the peak envelope power of the digital modulation.

For example, if the desired channel is DTTV-24 and a strong, -10 dBm channel DTTV-34 modulates the adjacent DTTV-25, which is also strong at –10 dBm, then the XM splatter from channel 25 to channel 24 for IP_3=4 dBm and for IP_3=16 dBm would be:

$$XM= 2*(-10-4)-10-8=-46 \text{ dBm} \quad \text{for } IP_3=4 \text{ dBm}$$
$$XM= 2*(-10-16)-10-8=-70 \text{ dBm} \quad \text{for } IP_3=16 \text{ dBm}$$

Future generations of DTTV receivers are expected to have passband filter that is 3-channels wide. With such a filter the XM splatter from the first adjacent channel would be negligible, and, as a practical matter could be ignored.

VII. SNR AT THE RECEIVER

The total noise power at the desired channel, ignoring phase noise, intersymbol interference noise, noise produced by higher than 3rd order nonlinear distortion at the receiver and the XM of the first adjacent channels by another channel, would be the sum of:

- Noise floor of the receiver.
- Man-made and sky noise.
- IM+XM generated at the desired channel by the transmitter's non-linearity, typically 27 to 32 dB below the desired power.
- IM+XM generated at the desired channel by the receiver's non-linearity. See equation (8).
- Sideband splatter generated by the transmitter of the adjacent channels. That splatter appears as cochannel interference. See Appendix B, equation (B3).
- Sideband splatter generated by the by strong adjacent channels at the receiver. That splatter appears as cochannel interference. See equation (10).

The SNR of the desired channel, based on the average power of the six sources of noise and interference is:

$$SNR = \frac{D}{N + (IM + XM)_{Tx} + (IM + XM)_{Rx} + I_{Tx} + I_{Rx}} \qquad (13)$$

where:
D = desired channel power.
N = sum of man-made and thermal noise.
$(IM+XM)_{Tx}$ = in-channel interference generated at the transmitter.
$(IM+XM)_{Rx}$ = in-channel interference generated at the receiver.
I_{Tx} = sideband splatter generated by the transmitter of the undesired adjacent channels.
I_{Rx} = sideband splatter generated by strong undesired adjacent channels at the receiver.

In equation (13), each of the two (IM+XM) terms is a nonlinear function of D, the desired channel power, and each of the two I terms is a nonlinear function of U, the undesired channel power.

VIII. D/U PROTECTION RATIOS FOR DTTV

For DTTV channels in the bands above 100 MHz, the sum of man-made and thermal noise, N, has been shown [2] to be in the range of –95 to –87 dBm depending on antenna configuration. For channels below 100 MHz, the sky noise becomes a significant factor.

The SNR of DTTV transmitters, ratio of the desired power to the in-channel sum of IM and XM interference generated by the desired channel transmitter, is typically 27 to 32 dB.

With the assumptions made above regarding the sum of man-made and thermal noise and the transmitter SNR, equation (13) can be solved for the available positive or negative margin relative to the SNR at TOV, which is 15.5 dB for 8-VSB modulation.

First, the D/U test results at the ATTC [3], [4] will be shown replicable by the theory developed in this paper. The analytical results of this paper cover the entire dynamic range under which the receiver is expected to operate.

Table IV is a replication of the initial tests conducted with a linear setup and without man-made noise. The test conditions are shown in the upper left box. The desired channel's transmitter is shown to be SNR=100 dB and the splatter from the undesired adjacent channel's transmitter into the desired channel is shown to be –100 dB below the undesired power. Only thermal noise at –96 dBm is assumed. Selecting D between –65 and –70 dBm and U at –25 dBm we find that the expected margin would fall between –3 and +2 dBm (bold fonts). This is as close as possible to the test results shown in Table II where TOV (0 margin) was observed at D=-68 dBm and U=-25.5 dBm. Had the ATTC tests been performed with different but no less practical levels for D and U, some of the flaws in the tests would have been apparent. For example, for D=-35 dBm and U=-10 dBm, or D/U=-25 dB, the SNR margin is –13 dB below TOV.

In Table V, the nonlinear distortion expected from a practical transmitter was included and some man-made noise was added to the thermal noise. The test receiver's IP_3 is still the same 4 dBm that was estimated earlier in this paper. TOV is reached at D between –65 and -70 dBm and U=-40 dBm or D/U between -30 dB and –25 dB. This seems like an improvement and it is in line with the FCC latest revision[§] where –26 dB<D/U<-27 dB. However, for D=-35 dBm and U=-10 dBm, or D/U=-25 dB, the SNR margin is still –13 dB below TOV. Therefore, the new protection ratios codified into the FCC rules are still inconsistent with the dynamic range of operation expected from receivers with IP_3 of approximately 4 dBm or lower.

Ideally, to cover the dynamic the entire table of SNR margins should be several dB above zero. That may not be possible practically for transmission systems where the D/U ratio cannot be limited by system design. Distributed transmitters on the adjacent channel with coverage overlap of the desired channel is an example of a system where potentially $-\infty<D/U<+\infty$. However, for most transmission systems, certain precautions together with an improved design of the receiver's front end, would alleviate most of the undesired interference by strong first adjacent channels.

Table VI shows the substantial improvement expected from a receiver with IP_3=16 dBm. Overload of the front end by the desired channel alone is gone but significant interference from the first adjacent channel is still present for some D/U≤–40 dB.

Table VII shows that if the man-made noise were increased to its maximum expected at 69 MHz, and the SNR at TOV were to be given a 3 dB margin to account for interference from two adjacent channels and other sources of noise, then IP_3 of 32 dB would be desirable.

Even with IP_3>32 dBm there remains a region of negative margins relative to TOV for very negative D/U ratios (strong U) as seen in the upper right area of Tables IV-VII. The conversion of the negative into positive margins would require a "smart" receiver design [9] that allows for a significant reduction in the level of the undesired adjacent channel at the active stages of the receiver.

CONCLUSIONS AND RECOMMENDATIONS

The allowable interference from adjacent channels codified in the FCC Regulations [§73.623] and in FCC Bulletin OET-69 is incompatible with the dynamic range expected from DTTV receivers. The reasons for the variance are:

- The allowable interference ignores strong interferor signals at the receiver.
- The distortion by multiple channels has been ignored.
- The dependence of D/U ratios on man-made and sky noise has been ignored.
- The presumptions of one transmitting antenna for both desired/adjacent channels and highly directional receive antenna are questionable generally and particularly for low-power television (LPTV) and for distributed transmission.

To protect consumers and broadcasters from the expected interference in a packed spectrum, LPTV stations should also be collocated on the same tower of their first adjacent channels. Minimal receiver specifications, such as $IP_3 \geq 16$ dBm and a dynamic range consistent with the FCC's allotted power and planning factors should be mandated. The expected interference could be drastically reduced with a "smart" receiver and lowered transmitter sideband splatter. A "smart" receiver such as that described in [9] would use a combination of shifted passband filter, inserted attenuation and a steerable antenna pattern to drastically reduce the level of all undesired channels at the input of the receiver.

For distributed transmission, unless all adjacent channels are collocated on all distributed antennas, a practical protection ratio may not be easily defined. Therefore, unless all adjacent channels are collocated, distributed transmission on first adjacent channels should not be permitted if the coverage area of the distributed system overlaps the service area of victimized channels.

APPENDIX A: TRADITIONAL INTERMODULATION ANALYSIS

Traditional analysis of IM is based on IM_3 frequencies generating new carriers when passed through a non-linear circuit. The cubic term of the non-linearity is responsible for the generation of IM_3, which generates new frequencies and XM, which does not. If $f_1 < f_2$, the newly generated IM_3 frequencies are at $2f_1 - f_2$, which is below f_1, and at $2f_2 - f_1$, which is above f_2. The amount of power transferred from the input power to the undesired IM_3 frequencies can be derived with the aid of Fig. A1. The fundamental input/output power has a 1:1 linear slope and the IM_3 input/output power has a 3:1 linear slope. The fictitious IP_3 (3rd order intercept point level) is the point where the IM3 power is equal to the fundamental power output. The two curves of Fig. A1 apply only for G=20 dB and IP_3=40 dBm. For lower gain and same IP_3, the two curves are shifted to the right.

From the geometry and the definitions of Fig.A1 it can be easily shown that if the two carriers at the input to the device, f_1 and f_2, have equal power, then the power of IM_3 at $2f_1 - f_2$ and $2f_2 - f_1$ is:

$$IM_3(dBm) = 3P_{out}(dBm) - 2IP_3(dBm) \quad (A1)$$

[§] The assignment of two different ratios, one for the upper and one for the lower adjacent DTTV channel is a result of experimental error that unfortunately went unrecognized.

If the two carriers at the input are of unequal power, it can be shown[**] that referring to the output:

$$IM_3(@2f_1 - f_2) = 2P_{in}(f_1) + P_{in}(f_2) + 3G - 2IP_3 \quad (A2)$$
$$IM_3(@2f_2 - f_1) = 2P_{in}(f_2) + P_{in}(f_1) + 3G - 2IP_3$$

where:
G=Gain of the device in dB
P_{out}(dBm)= P_{in}(dBm) + G

Therefore, knowledge of IP_3 and the input power determine the IM_3 level so long as the device's input/output follows the straight lines with the correct slopes. In reality, practical active devices may not have the theoretical input/output behavior. For example, the dashed lines in Fig.A1 show how the output power gets saturated at high input power. That is the reason why the IP_3 is fictitious and can only be achieved by extrapolation. The analysis thus applies only to input power well below IP_3. In the case of broadband signals such as DTTV, the two-tone analysis does not provide the spectral density of the IM_3 and XM products that is given in Section V.

APPENDIX B: ALLOWABLE NOISE POWER IN ADJACENT CHANNELS

8-VSB DTTV
The slope of the FCC mask is defined as:

Relative Power (dB) = -11.5(ΔF+3.6) where ΔF is in MHz from channel edge through the adjacent channel.

As shown in Figure B1, the total in-channel power is 10.63 dB above 0 dB and at the first .5 MHz of the adjacent channel the spectral density is –36.52 dB relative to 0 dB or 47.15 dB relative to the total noise-free in-channel power.

The allowable noise power splatter into the adjacent channel relative to the *useful* in-channel power is:

$$ACPR\,(dB) = -44.71 - 10Log\left(1 - 10^{-SNR_{Tx}/10}\right) \quad (B1)$$

where:
SNR_{Tx} (dB) is the transmitter's SNR.

At the receiver, the Nyquist filter implementation reduces the sideband splatter by an additional 1.8 dB so that the sideband splatter, I, into the desired adjacent channel is given by:

$$\frac{\mathrm{I}}{\mathrm{U}}(dB) = -46.50 - 10Log\left(1 - 10^{-SNR_{Tx}/10}\right) \quad (B2)$$

where:
U = in-channel power of the undesired adjacent channel.

The allowable splatter in the adjacent channel relative to the *total* in-channel power is:

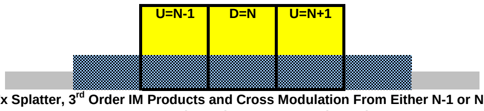
$$\frac{\mathrm{I}}{\mathrm{U}}(dB) = -46.50 \quad (B3)$$

NTSC
There are several FCC rules governing the maximum permissible sideband splatter of NTSC channels. A clear interpretation of the rules governing the allowable NTSC splatter has been published [10]. Unlike the DTTV case, the interference power in the adjacent channel is not continuous but is made of discrete frequencies resulting from the mixing of visual, aural and colors subcarrier.

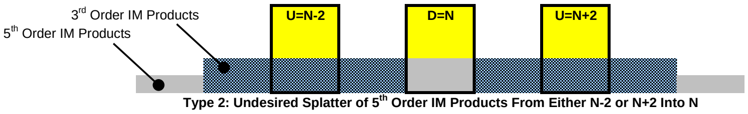
Relative to the visual carrier frequency, the discrete IM_3 products would be at +5.42 MHz, +7.16 MHz and +9 MHz in the upper adjacent channel and at -3.58 MHz and –4.5 MHz in the lower adjacent channel.

[1] O. Bendov, J.F.X. Browne, C.W. Rhodes, Y. Wu and P. Bouchard, " DTV Coverage and Service Prediction, Measurement and Performance Indices," IEEE Transactions on Broadcasting, Vol. 47, September 2001.
[2] O. Bendov, Y. Wu, C.W. Rhodes and J.F.X. Browne, "Planning Factors for Fixed and Portable DTTV Reception," Presented at the 53rd IEEE Broadcast Symposium, October 17,2003. To be published in the September 2004 issue of the IEEE Transactions on Broadcasting.
[3] ATTC, Record of Test Results, Digital HDTV Grand Alliance System, October 1995.
[4] An Evaluation of the FCC RF Mask for the Protection of DTV Signals from Adjacent Channel DTV Interference, Advanced Technology Test Center, Document # 97-06, July 17, 1997.
[5] Qiang Wu, Heng Xiao and Fu Li, "Linear RF Power Amplifier Design for CDMA Signals: A Spectrum Analysis Approach," Microwave Journal, December 1998.
[6] J.C. Pedro and N.B. Carvalho, *Intermodulation Distortion in Microwave and wireless circuits*, Artech House 2003.
[7] U.L. Rohde and D.P. Newkirk, *RF/Microwave Circuir Design for Wireless Applications*, John Wiley & Sons 2000.
[8] Y. Zhang, "Cross-modulation in a CDMA Mobile Phone Receiver," Microwave Journal, October 2003.
[9] O. Bendov and C.B. Patel, "Television Receiver Optimization in the Presence of Adjacent Channel Interference," to be published in the IEEE Transactions on Broadcasting.
[10] Dane E. Ericksen, "Measuring TV Sidebands & Spurious Emissions," Broadcast Engineering, May 1982.
[11] O. Bendov, The Effect of Channel Assignment on Transmitter and Receiver Requirements for Equivalent HDTV/NTSC Coverage," 48th Annual Broadcasting Engineering Conference Proceedings, 1994 NAB, Las Vegas, NV.

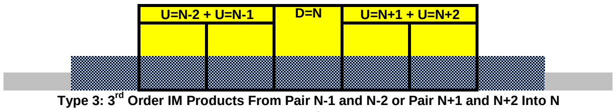
[**] Through tedious algebraic analysis



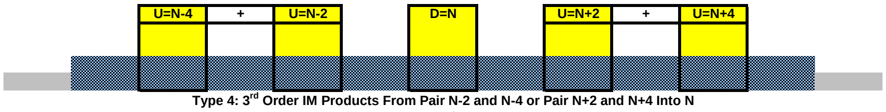
Type 1: Undesired Tx Splatter, 3rd Order IM Products and Cross Modulation From Either N-1 or N+1 Into N
118 DTTV Channels + 128 NTSC Channels



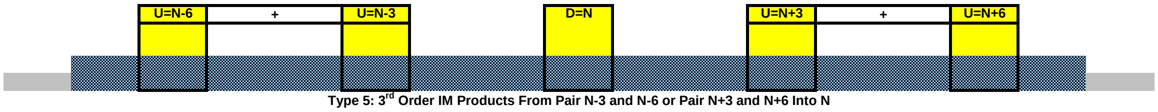
Type 2: Undesired Splatter of 5th Order IM Products From Either N-2 or N+2 Into N



Type 3: 3rd Order IM Products From Pair N-1 and N-2 or Pair N+1 and N+2 Into N
35 Stations



Type 4: 3rd Order IM Products From Pair N-2 and N-4 or Pair N+2 and N+4 Into N
27 Stations



Type 5: 3rd Order IM Products From Pair N-3 and N-6 or Pair N+3 and N+6 Into N
13 Stations

Figure 1: Types of DTTV Interference to the Desired Channel D=N by Adjacent Channels Within a Tuner Passband of 18-78 MHz
At least 287 channels, some victimized by more than one type

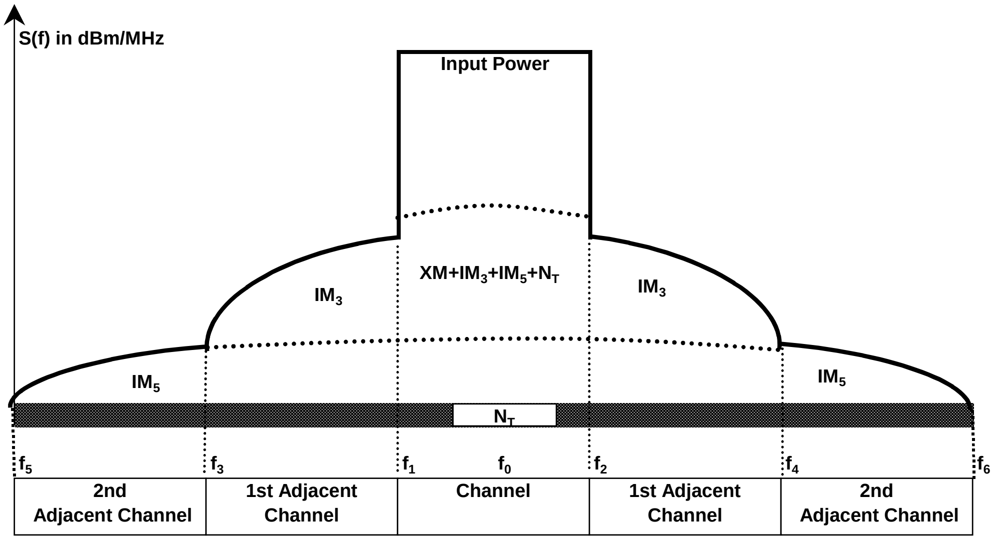


Figure 2: Components of Spectral Power Density S(f)

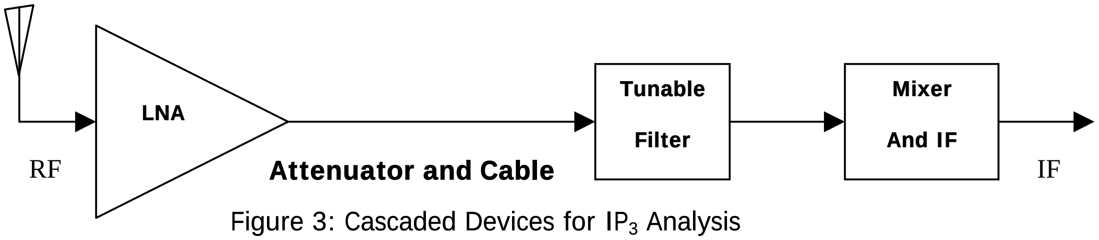


Figure 3: Cascaded Devices for IP_3 Analysis

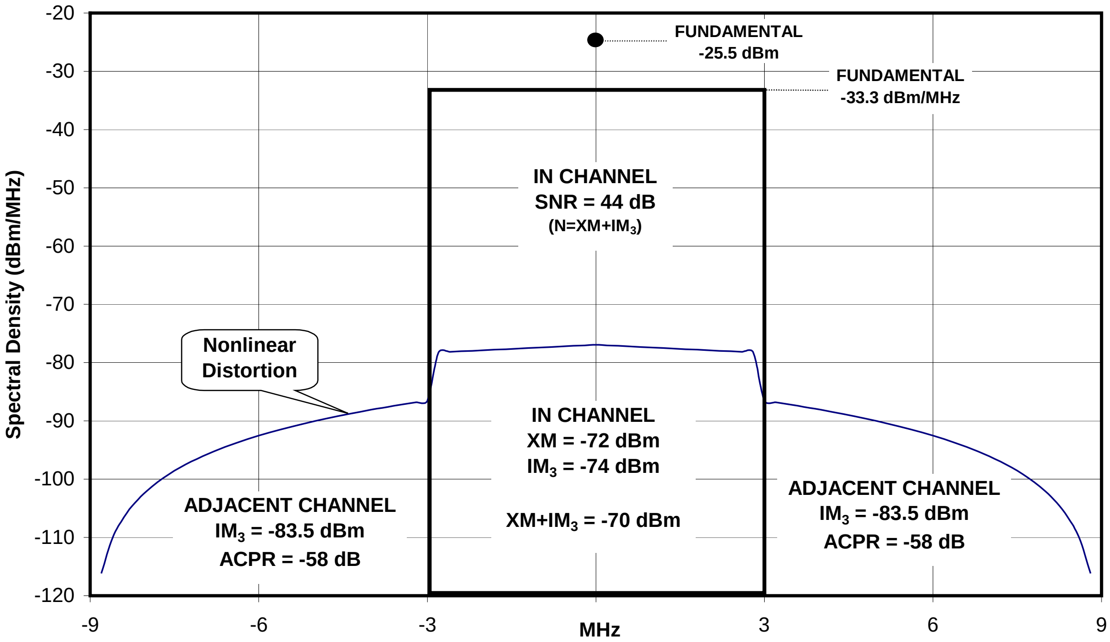


Figure 4: Spectral Density for Fundamental = -25.5 dBm and IP_3 = 3.5 dBm

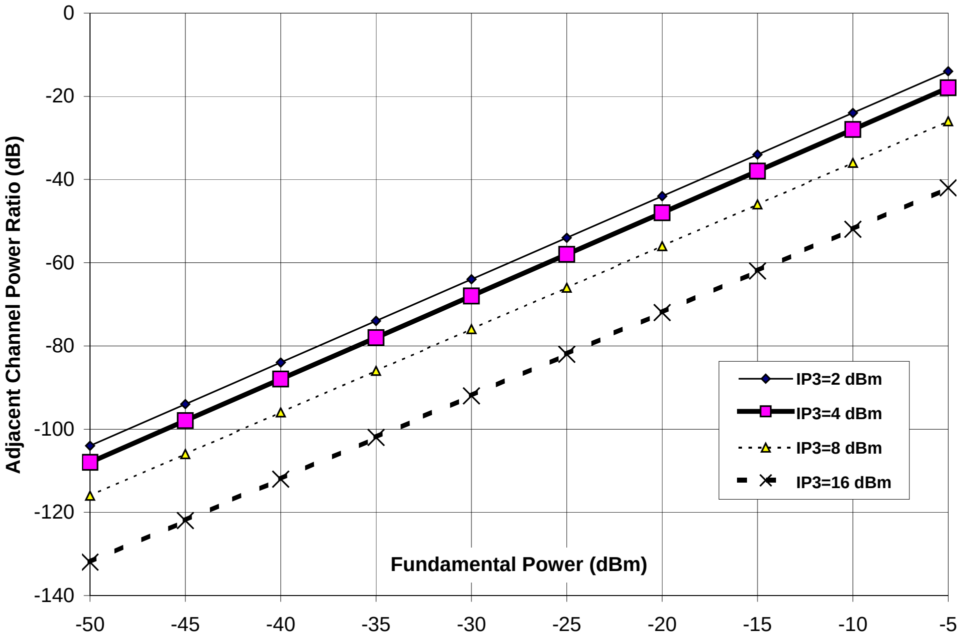


Figure 5: IM$_3$ Power in Adjacent Channel

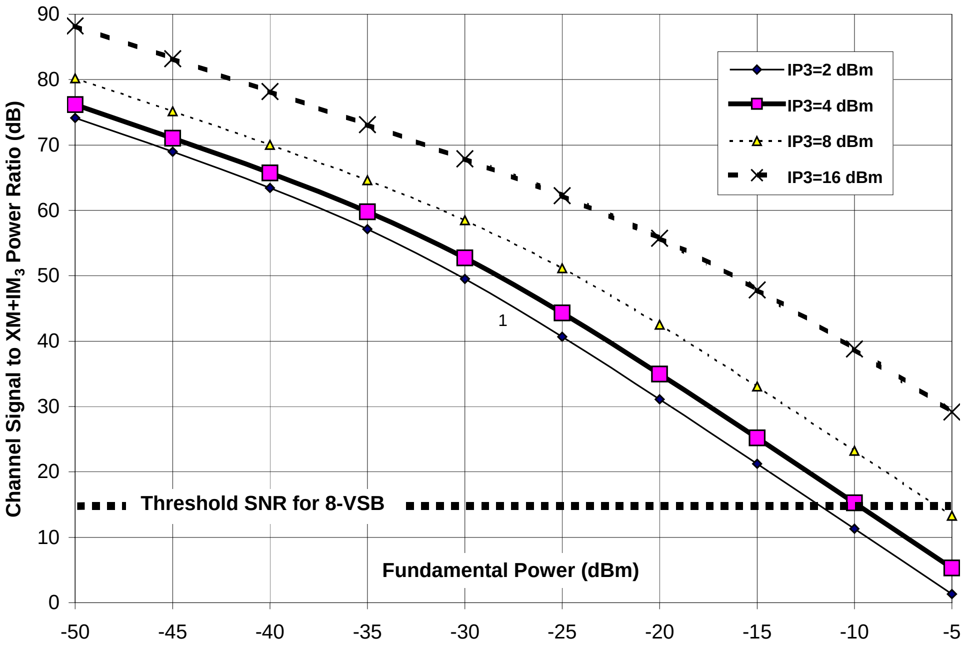


Figure 6: Channel SNR

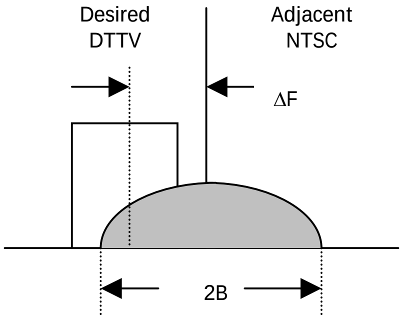


Figure 7: XM Spectrum

Station	Desired DTV ch.	DTV ERP	NTSC ch.	NTSC ERP	First Adjacent Channel	Undesired Channel Pair into Desired DTV (3rd Order IM)											
						N-3	N-6	N-2	N-4	N-1	N-2	N+3	N+6	N+2	N+4	N+1	N+2
Miami																	
WSVN	**8**	145	7	316	**7N, 9D**			**6**	**4**								
WPLG	**9**	30	10	316	**8D, 10N**					**8**	**7**						
WPBT	**18**	1000	2	100	**19D, 17N**									**20**	**22**	**19**	**20**
WBZL	**19**	1000	39	5000	**18D, 20D**					**18**	**17**						
WLRN	**20**	625	17	2825	**19D**					**19**	**18**			**22**	**24**		
WFOR	**22**	1000	4	100	**23N**			**20**	**18**					**24**	**26**		
WLTV	**24**	500	23	4470	**23N**			**22**	**20**	**23**	**22**						
WPXM	**26**	200	35	3240				**24**	**22**								
WTVJ	**31**	1000	6	100	**32D**									**33**	**35**	**32**	**33**
WBFS	**32**	1000	33	5000	**31D, 33N**												
WHFT	**46**	500	45	2570	**45N**												
WSCV	**52**	500	51	5000	**51N**												
Denver																	
KUSA	**16**	1000	9	316	**D17**									**18**	**20**	**17**	**18**
KMGH	**17**	1000	7	316	**D18**											**18**	**19**
KRMA	**18**	1000	6	100	**D17, D19**					**17**	**16**						
KTVD	**19**	655	20	5000	**D18, N20**					**18**	**17**						
KDVR	**32**	223	31	5000	**N31**												
KWGN	**34**	1000	2	100	**D35**												
KCNC	**35**	490	4	100	**D34**												
KRMT	**40**	75	41	741	**N41**												
KCEC	**51**	900	50	2510	**N50**												
District of Columbia-Baltimore																	
WETA	**27**	90	26	2250	**N26**												
WHUT	**33**	100	32	5000	**D34, N32**							**36**	**39**			**34**	**35**
WUSA	**34**	646	9	646	**D33, D35**					**33**	**32**					**35**	**36**
WDCA	**35**	232	20	5000	**D34, D36**					**34**	**33**						
WTTG	**36**	1000	5	100	**D35**			**34**	**32**	**35**	**34**						
WJLA	**39**	640	7	316		**36**	**33**										
WBDC	**51**	100	50	2450	**N50**												
WNUV	**40**	845	54		**D41,D39**												
WUTB	**41**	25	24	1170	**D40**					**40**	**39**						
WBFF	**46**	550	45	1290	**N45**												

Table I: Examples of Interference in Miami, Denver and the District of Columbia

	D & U in dBm		FCC	ATTC		
	Undesired	Desired	D/U	D/U	D	U
U=N-1	DTTV	DTTV	**-42**	**-42**	**-68**	**-26**
	NTSC	DTTV	**-48**	**-48**	**-68**	**-20**
D=U =N	DTTV	DTTV	**15**	**15**	**-68**	**-53**
	NTSC	DTTV	**2**	**2**	**-68**	**-66**
U=N+1	DTTV	DTTV	**-43**	**-43**	**-68**	**-25**
	NTSC	DTTV	**-49**	**-49**	**-68**	**-19**

Table II: ATTC Test 1995 Results and Original FCC D/U

		ERP (kW)		
Call	**Channel**	**Analog**	**Digital**	**LPTV**
KERA	14		475	
KTXA	18		220	
KTVT	19		565	
KTXA	21	5000		
K25FW	25			47
KDFI	27	5000		
KDAF	32		780	
KDAF	33	5000		
KDFW	35		857	
KDFI	36		1000	
KVFW	38			112
KXTX	39	5000		
KXTX	40		1000	
KXAS	41		891	
KPXD	42		1000	
KDTX	45		1000	
KSTR	48		225	
KSTR	49	4470		
KFWD	51		375	
KFWD	52	5000		
KSEX	57			100
KDTX	58	5000		
KPXD	68	5000		
Total ERP:		**39470**	**8388**	**259**

Table III: Total ERP Expected From Cedar Hill, Dallas, Texas.

SNR atTx=				**100**	dB	I_{TX}=Sideband Splatter from Adjacent Channel Tx (dBm)														
Man-made & Thermal						-170	-165	-160	-155	-150	-145	-140	-135	-130	-125	-120	-115	-110	-105	-100
Noise at Rx=				**-96**	dBm	I_{RX}=Sideband Splatter from Adjacent Channel at the Rx (dBm)														
SNR at TOV=				**15.5**	dB	-218	-203	-188	-173	-158	-143	-128	-113	-98	-83	-68	-53	-38	-23	-8
Rx 3rd Order Intercept=				**4**	dBm	**Undesired Adjacent Channel Power (dBm)**														
Tx Sideband Splatter=				**-100**	dB	**-70**	**-65**	**-60**	**-55**	**-50**	**-45**	**-40**	**-35**	**-30**	**-25**	**-20**	**-15**	**-10**	**-5**	**0**
$(IM+XM)_{Tx}$=In-channel Interference Generated at the Tx (dBm)	-170	**$(IM_3+XM)_{Rx}$=In-channel Interference Generated at the Rx (dBm)**	-166	**Desired Channel Power (dBm)**	**-70**	10	10	10	10	10	10	10	10	8	**-3**	-18	-33	-48	-63	-78
	-165		-156		**-65**	15	15	15	15	15	15	15	15	13	**2**	-13	-28	-43	-58	-73
	-160		-146		**-60**	20	20	20	20	20	20	20	20	18	7	-8	-23	-38	-53	-68
	-155		-136		**-55**	25	25	25	25	25	25	25	25	23	12	-3	-18	-33	-48	-63
	-150		-126		**-50**	30	30	30	30	30	30	30	30	28	17	2	-13	-28	-43	-58
	-145		-116		**-45**	35	35	35	35	35	35	35	35	33	22	7	-8	-23	-38	-53
	-140		-106		**-40**	40	40	40	40	40	40	40	40	38	27	12	-3	-18	-33	-48
	-135		-95		**-35**	42	42	42	42	42	42	42	42	41	32	17	2	-13	-28	-43
	-130		-83		**-30**	37	37	37	37	37	37	37	37	37	34	22	7	-8	-23	-38
	-125		-69		**-25**	29	29	29	29	29	29	29	29	29	29	25	12	-3	-18	-33
	-120		-55		**-20**	19	19	19	19	19	19	19	19	19	19	19	15	2	-13	-28
	-115		-40		**-15**	10	10	10	10	10	10	10	10	10	10	10	9	5	-8	-23
	-110		-25		**-10**	0	0	0	0	0	0	0	0	0	0	0	0	0	-5	-18
	-105		-10		**-5**	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-15
	-100		5		**0**	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20

▨ D/U<-30 dB ░ D/U>=-30 dB

Table IV: Margin in dB Over TOV for Receiver IP_3=4 dBm Assuming Linear Transmitter and no Man-made Noise

SNR atTx=				**32**	dB	I_{TX}=Sideband Splatter from Adjacent Channel Tx (dBm)														
Man-made & Thermal						-117	-112	-107	-102	-97	-92	-87	-82	-77	-72	-67	-62	-57	-52	-47
Noise at Rx=				**-90**	dBm	I_{RX}=Sideband Splatter from Adjacent Channel at the Rx (dBm)														
SNR at TOV=				**15.5**	dB	-218	-203	-188	-173	-158	-143	-128	-113	-98	-83	-68	-53	-38	-23	-8
Rx 3rd Order Intercept=				**4**	dBm	**Undesired Adjacent Channel Power (dBm)**														
Tx Sideband Splatter=				**-46.5**	dB	**-70**	**-65**	**-60**	**-55**	**-50**	**-45**	**-40**	**-35**	**-30**	**-25**	**-20**	**-15**	**-10**	**-5**	**0**
$(IM+XM)_{Tx}$=In-channel Interference Generated at the Tx (dBm)	-102	**$(IM_3+XM)_{Rx}$=In-channel Interference Generated at the Rx (dBm)**	-166	**Desired Channel Power (dBm)**	**-70**	4	4	4	4	3	2	**-1**	-5	-9	-14	-21	-33	-48	-63	-78
	-97		-156		**-65**	9	9	9	8	8	7	**4**	0	-4	-9	-16	-28	-43	-58	-73
	-92		-146		**-60**	12	12	12	12	12	11	9	5	1	-4	-11	-23	-38	-53	-68
	-87		-136		**-55**	15	15	15	15	14	14	12	9	5	1	-6	-18	-33	-48	-63
	-82		-126		**-50**	16	16	16	16	16	15	15	13	10	5	-1	-13	-28	-43	-58
	-77		-116		**-45**	16	16	16	16	16	16	16	15	13	10	3	-8	-23	-38	-53
	-72		-106		**-40**	16	16	16	16	16	16	16	16	15	13	8	-3	-18	-33	-48
	-67		-95		**-35**	16	16	16	16	16	16	16	16	16	15	12	2	-13	-28	-43
	-62		-83		**-30**	16	16	16	16	16	16	16	16	16	16	14	6	-8	-23	-38
	-57		-69		**-25**	16	16	16	16	16	16	16	16	16	16	16	11	-3	-18	-33
	-52		-55		**-20**	15	15	15	15	15	15	15	15	15	15	15	13	2	-13	-28
	-47		-40		**-15**	9	9	9	9	9	9	9	9	9	9	9	9	5	-8	-23
	-42		-25		**-10**	0	0	0	0	0	0	0	0	0	0	0	0	-1	-5	-18
	-37		-10		**-5**	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-15
	-32		5		**0**	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20	-20

▨ D/U<-30 dB ░ D/U>=-30 dB

Table V: Margin in dB Over TOV for Receiver IP_3 = 4 dBm

SNR atTx= **32** dB
Man-made & Thermal
Noise at Rx= **-90** dBm
SNR at TOV= **15.5** dB
Rx 3rd Order Intercept= **16** dBm
Tx Sideband Splatter **-46.5** dB

						I_{TX}=Sideband Splatter from Adjacent Channel Tx (dBm)														
						-117	-112	-107	-102	-97	-92	-87	-82	-77	-72	-67	-62	-57	-52	-47
						I_{RX}=Sideband Splatter from Adjacent Channel at the Rx (dBm)														
						-242	-227	-212	-197	-182	-167	-152	-137	-122	-107	-92	-77	-62	-47	-32
						Undesired Adjacent Channel Power (dBm)														
						-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0
$(IM+XM)_{Tx}$=In-channel Interference Generated at the Tx (dBm)	-102	**$(IM_3+XM)_{Rx}$=In-channel Interference Generated at the Rx (dBm)**	-178	**Desired Channel Power (dBm)**	-70	4	4	4	4	3	2	-1	-5	-9	-14	-19	-24	-30	-40	-54
	-97		-168		-65	9	9	9	8	8	7	4	0	-4	-9	-14	-19	-25	-35	-49
	-92		-158		-60	12	12	12	12	12	11	9	5	1	-4	-9	-14	-20	-30	-44
	-87		-148		-55	15	15	15	15	14	14	12	9	5	1	-4	-9	-15	-25	-39
	-82		-138		-50	16	16	16	16	16	15	15	13	10	6	1	-4	-10	-20	-34
	-77		-128		-45	16	16	16	16	16	16	16	15	13	10	6	1	-5	-15	-29
	-72		-118		-40	16	16	16	16	16	16	16	16	15	13	10	6	0	-10	-24
	-67		-108		-35	16	16	16	16	16	16	16	16	16	15	13	10	5	-5	-19
	-62		-98		-30	16	16	16	16	16	16	16	16	16	16	15	13	9	0	-14
	-57		-87		-25	16	16	16	16	16	16	16	16	16	16	16	15	13	5	-9
	-52		-76		-20	16	16	16	16	16	16	16	16	16	16	16	16	15	9	-4
	-47		-63		-15	16	16	16	16	16	16	16	16	16	16	16	16	16	13	1
	-42		-49		-10	16	16	16	16	16	16	16	16	16	16	16	16	16	14	6
	-37		-34		-5	12	12	12	12	12	12	12	12	12	12	12	12	12	12	9
	-32		-19		0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3

🟦 D/U<-30 dB ⬜ D/U>=-30 dB

Table VI: Margin in dB Over TOV for Receiver IP_3 = 16 dBm

SNR atTx= **30** dB
Man-made & Thermal
Noise at Rx= **-87** dBm
SNR at TOV= **18.5** dB
Rx 3rd Order Intercept= **32** dBm
Tx Sideband Splatter **-46.5** dB

						I_{TX}=Sideband Splatter from Adjacent Channel Tx (dBm)														
						-117	-112	-107	-102	-97	-92	-87	-82	-77	-72	-67	-62	-57	-52	-47
						I_{RX}=Sideband Splatter from Adjacent Channel at the Rx (dBm)														
						-274	-259	-244	-229	-214	-199	-184	-169	-154	-139	-124	-109	-94	-79	-64
						Undesired Adjacent Channel Power (dBm)														
						-70	**-65**	**-60**	**-55**	**-50**	**-45**	**-40**	**-35**	**-30**	**-25**	**-20**	**-15**	**-10**	**-5**	**0**
$(IM+XM)_{Tx}$=In-channel Interference Generated at the Tx (dBm)	-100	**$(IM_3+XM)_{Rx}$=In-channel Interference Generated at the Rx (dBm)**	-194	**Desired Channel Power (dBm)**	**-70**	-2	-2	-2	-2	-2	-3	-5	-8	-12	-17	-22	-27	-32	-37	-42
	-95		-184		**-65**	3	3	3	3	2	2	0	-3	-7	-12	-17	-22	-27	-32	-37
	-90		-174		**-60**	7	7	7	7	6	6	4	1	-3	-7	-12	-17	-22	-27	-32
	-85		-164		**-55**	9	9	9	9	9	9	8	6	2	-2	-7	-12	-17	-22	-27
	-80		-154		**-50**	11	11	11	11	11	10	10	9	6	2	-2	-7	-12	-17	-22
	-75		-144		**-45**	11	11	11	11	11	11	11	10	9	6	2	-2	-7	-12	-17
	-70		-134		**-40**	11	11	11	11	11	11	11	11	11	9	6	2	-2	-7	-12
	-65		-124		**-35**	11	11	11	11	11	11	11	11	11	11	9	6	2	-2	-7
	-60		-114		**-30**	11	11	11	11	11	11	11	11	11	11	11	9	6	2	-2
	-55		-104		**-25**	11	11	11	11	11	11	11	11	11	11	11	11	9	6	2
	-50		-94		**-20**	11	11	11	11	11	11	11	11	11	11	11	11	11	9	6
	-45		-84		**-15**	11	11	11	11	11	11	11	11	11	11	11	11	11	11	9
	-40		-73		**-10**	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	-35		-62		**-5**	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	-30		-50		**0**	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11

🟦 D/U<-30 dB ⬜ D/U>=-30 dB

Table VII: Margin in dB Over TOV for Receiver IP_3 = 32 dBm Including 3 dB Margin over TOV and Noise

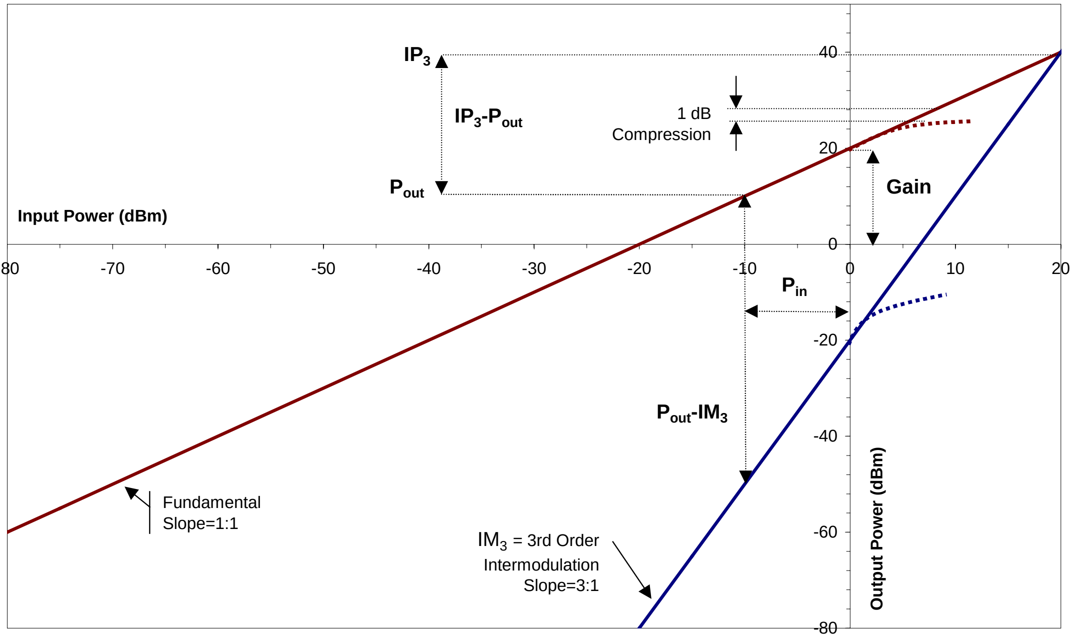


Figure A1: Third-Order Intermodulation Output Power
IP$_3$=40 dBm; Gain=20 dB

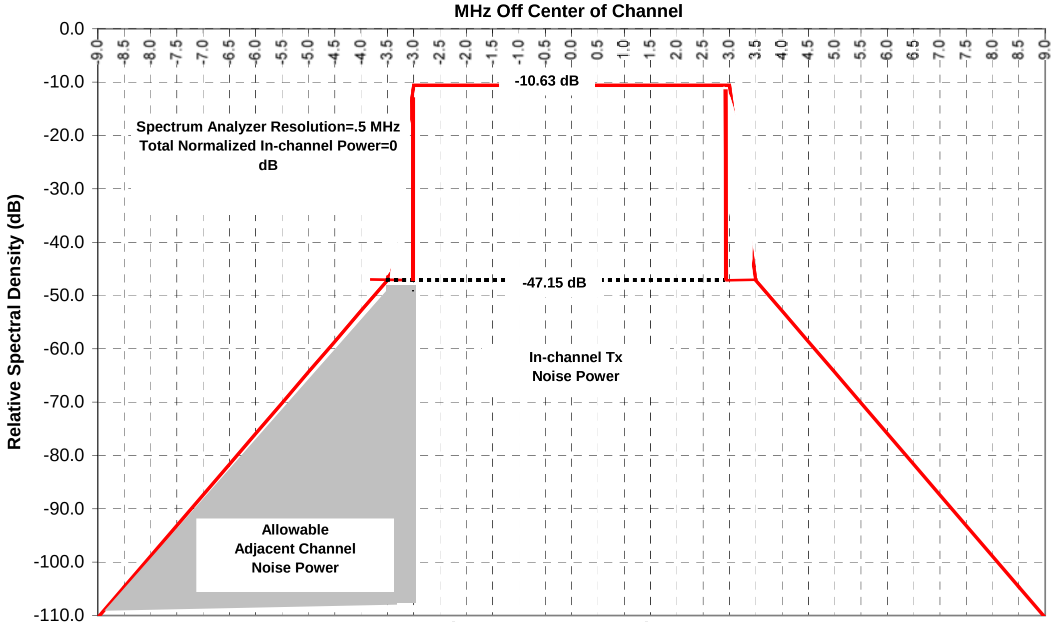


Figure B1: FCC Mask

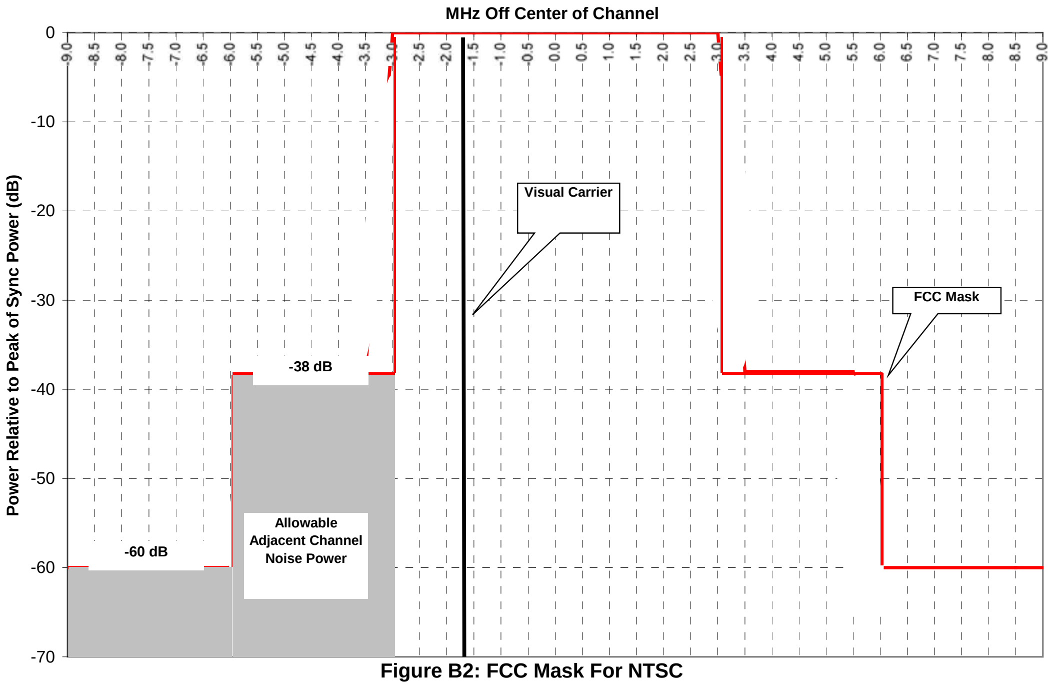


Figure B2: FCC Mask For NTSC