IBOC Coverage and Interference

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Introduction, we will look at HD coverage and the impact on analog coverage caused by HD interference.

1.) Testing shows that IBOC shows a “profound” improvement in multipath rejection

2.) In NRSC ticker testing, testers found nearly 1/5 as many audio impairments for HD than for analog over the same path.

3.) NRSC Laboratory tests showed that IBOC was significantly more robust than analog in the presence of a co-channel interferer and IBOC could handle a significant amount of Impulse noise that would impair FM Analog.

4.) IBOC performed better than the Analog host station in the presence of a single hybrid first-adjacent interferer and IBOC was “extremely more robust” with regard to single or dual 2nd adjacent hybrid interferers.

5.) IBOC receivers will exhibit full stereo under conditions when most analog receivers have blended to monaural.

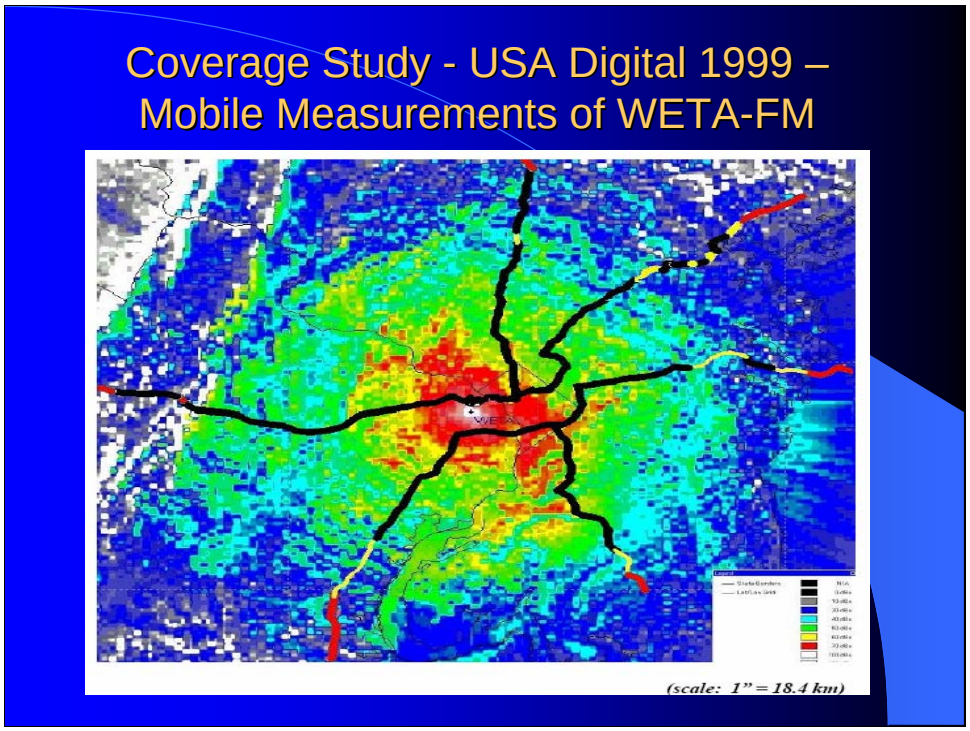
6.) AM IBOC sounds significantly better than analog

7.) IBOC has additional data capacity – minimum 3-4 kbps, up to 35-36 kbps when the main channel audio bit rate was reduced from 94 kbps to 64 kbps.

8.) IBOC offers the possibility of OFDM synchronization, which could allow IBOC boosters or single frequency networks.

9.) IBOC brings the opportunity of Multicasting (Not part of NRSC Study) – the most likely combination is where the main channel is reduced to 64 or 48 kbps and the second channel HD2 runs 28 kbps or 48 kbps. There are now HD3 stations broadcasting.

10.) NRSC study concludes that IBOC has similar coverage to Analog.

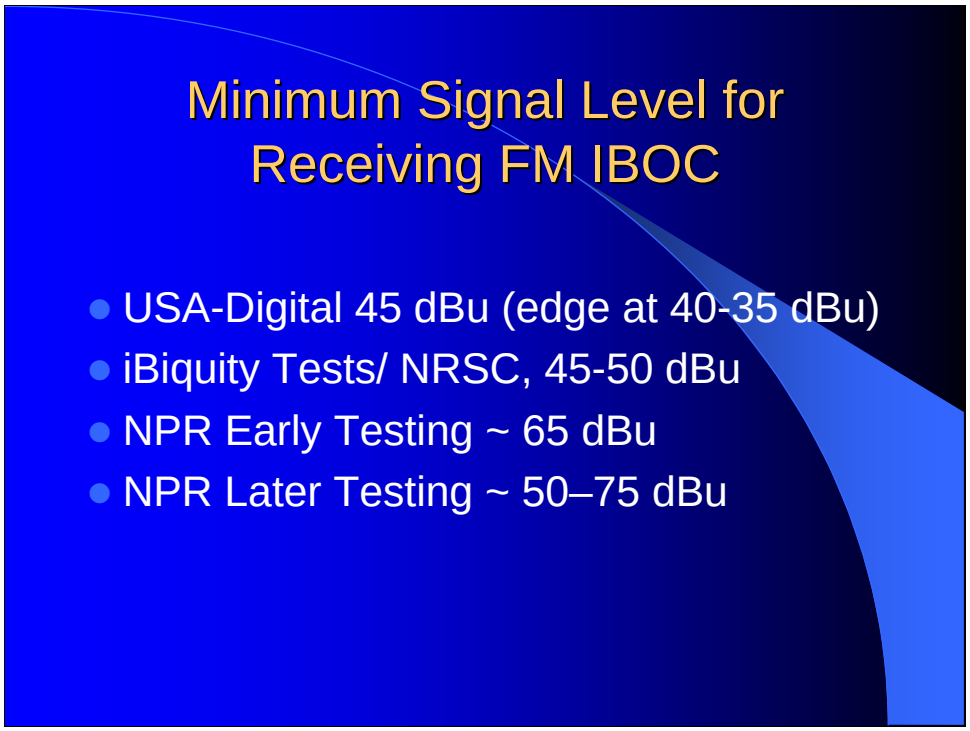


Let's talk about the issues relating to HD coverage. We'll start with this slide from USA Digital's 1999 FCC filing.

HD radio was called DAB then. Except for the codex algorithm, this system is basically what we are using today (MPEG-2 AAC) or PAC. Current IBOC uses the HDC algorithm.

This map of WETA-FM, in Washington, D.C., made by USA Digital for an FCC presentation, shows the drive path over which the mobile digital measurements of the hybrid signal were made using a high quality reference receiver and then superimposed over predicted coverage. Here, the green color represents the ~60 dBu signal range. The light blue is the 40 dBu signal range, while the dark blue is the 20 dBu signal area. The drive track, sometimes called a 'snail trail', is colored black when DAB was being received, yellow when DAB blended to analog and red when both the digital and analog signal were of such poor quality that listening ceased. From these tests, USA Digital determined that the 45 dBu was the usual signal strength for blend to analog, but there could be some reception of the digital signal to the 35 dBu. The coverage toward Baltimore (northeast) is reduced due both to terrain and urban environmental noise.

Under iBiquity's criteria, blending of HD to analog occurs when the Block Error Rate, exceeds 1 or more uncorrectable errors per block, or ten %.



So, as we have shown, the USA-Digital Blending point was defined at 45 dBu; with the edge between 30 and 35 dBu. This test was based on one station, WETA-FM.

In 2001 iBiquity field tested 8 FM stations and concluded that “In all cases digital coverage extended to 45-50 dBu.”

iBiquity currently recommends the 55 dBu signal contour.

NPR, working with Hammett and Edison, defined the HD coverage at the ~66 dBu.

This year, after measuring some 26 stations NPR showed the blend threshold to be variable from ~ 50 to 75 dBu

FM Coverage Availability Measurements (NPR)

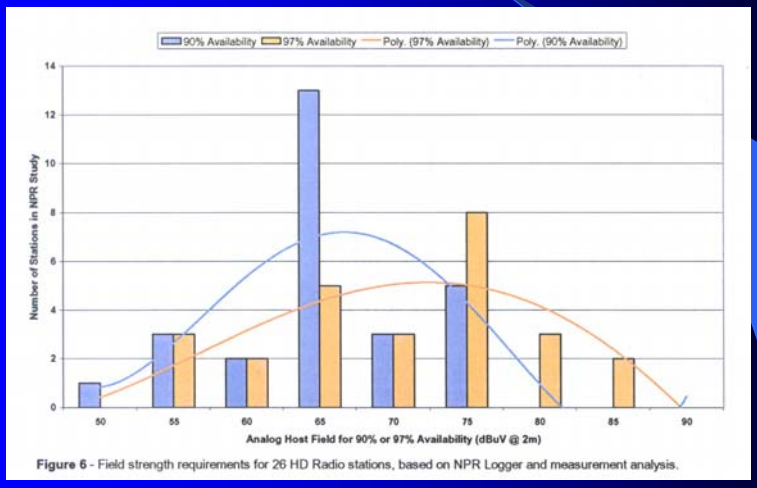


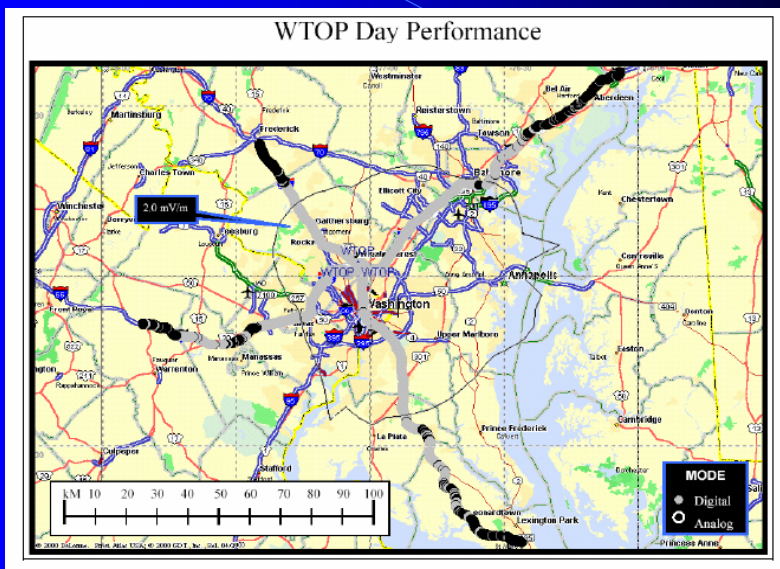
Figure 6 - Field strength requirements for 26 HD Radio stations, based on NPR Logger and measurement analysis.

NPR measured 26 stations using a unique HD logger of its own invention. This graph (courtesy of NPR) plots the number of stations on the vertical axis against the signal strength at which the HD to analog blend points occur on the horizontal axis.

NPR also brought in to play an “availability” factor, so the blue bars represent the signal strength for at least 90% of the time and the brown bars represent the availability for 97 percent of the time (an availability factor meeting the needs of HD2 multicast where there is no fallback to analog.)

NPR’s was surprised at the variability of HD coverage signal measurements and they indicated that more study was required to find out why.

IBOC AM Day Performance



This is a USA-Digital day-time test of the WTOP IBOC signal. Note that it slightly exceeds the station's 2 mV/m daytime contour in all directions.

AM Night time IBOC coverage

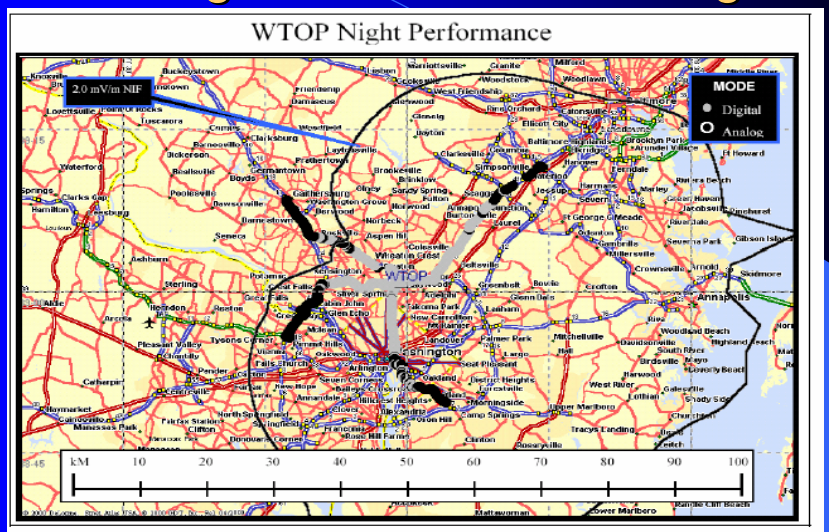
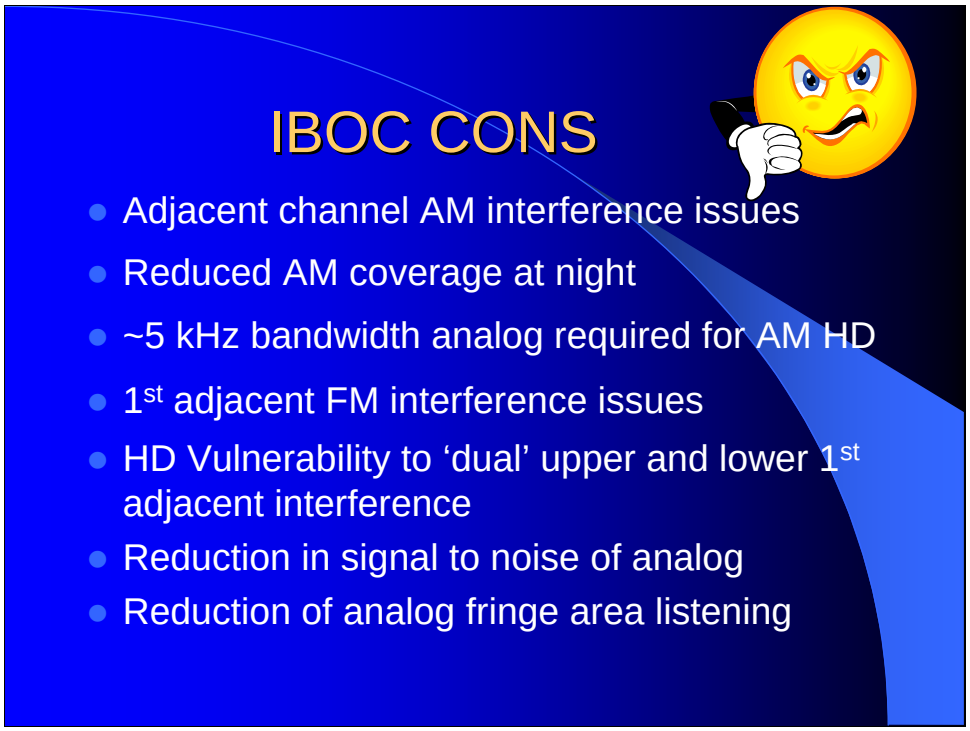


Figure 25. Coverage map including IBOC digital coverage (on radials) and NIF contour

At night, the story is different, the IBOC serves a much smaller area, well inside the 2mV/m 'night-time interference-free' contour of WTOP. The reduced coverage area is blamed on the impact of skywave propagation from co and adjacent station's.



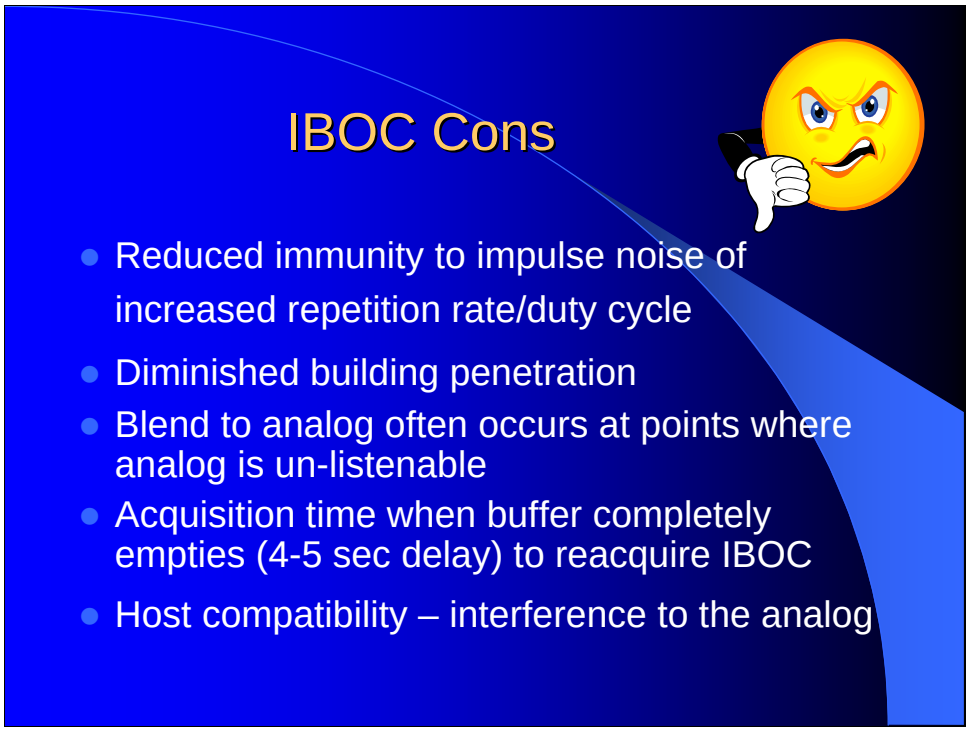
NRSC, Part 2 AM study; The Field test results indicate that AM listeners using automobile receivers will find that the quality of their audio goes from "good-to-fair" when a first adjacent stations begins IBOC transmissions and the 1st adjacent station is 15 dB weaker than the desired station. Listeners using a home hi-fi receiver will find their audio goes from fair-to-poor at the 15 dB point. Since the FCC allows a 1st adjacent station to be no less than 6 dB below the desired station, the +15 dB point will occur within the station's protected contour.

AM coverage at night is reduced due to required power and pattern setbacks and to the increased interference from distant stations.

Portable radio listeners will already experience interference from the analog and therefore are thought to exhibit no difference when HD was added.

20 out of 82 Mean Opinion Score (MOS) tests for 1st adjacent interference suggested a potential impact at signal levels within the normally protected contour of the station under test. Testing was done in the laboratory and in the field..

1st adjacent FM interference: With regard to the reduction of analog fringe listening, the NRSC report says that because the first adjacent HD digital side-band of a station occupies the same spectrum of another 1st adjacent station, that… "First adjacent channel compatibility is one of the most significant challenges for the FM-IBOC system. " NRSC tests of dual (both upper and lower) 1st adjacent interferers show that the interference to the HD occurs at when the undesired station is 21 dB below the desired station. when the opposite 1st adjacent station is least a 6 dB below with the desired station. For situations where there was only one 1st adjacent signal, IBOC performed



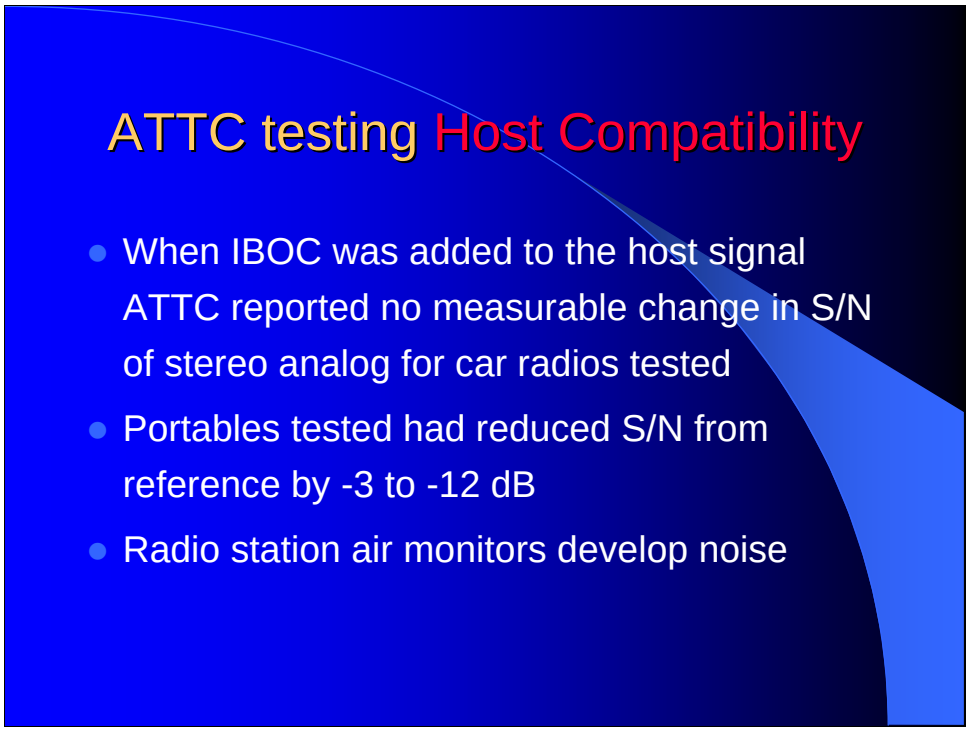
IBOC can be captured on a car receiver at idle but as the engine revs up the capture can be lost depending on the impulse noise generated by the car. In general, IBOC is less affected by impulse noise than analog.

Since the power of the IBOC is so small compared to typical analog power, building penetration is a real issue. Unless very close to the stations, IBOC receivers usually do not work inside commercial buildings on today's IBOC table model sets using the supplied antennas.

Testing has determined that radios will generally blend to analog at points where the analog signal begins to break up, consequently defeating the benefit of HD's fall back to analog when the HD signal gets shaky.

If the HD signal is lost for a period long enough to empty the buffer, reacquisition of the HD signal will require 4-5 seconds. If you are listening to HD2 some receivers will switch to analog and others will be silent during that time.

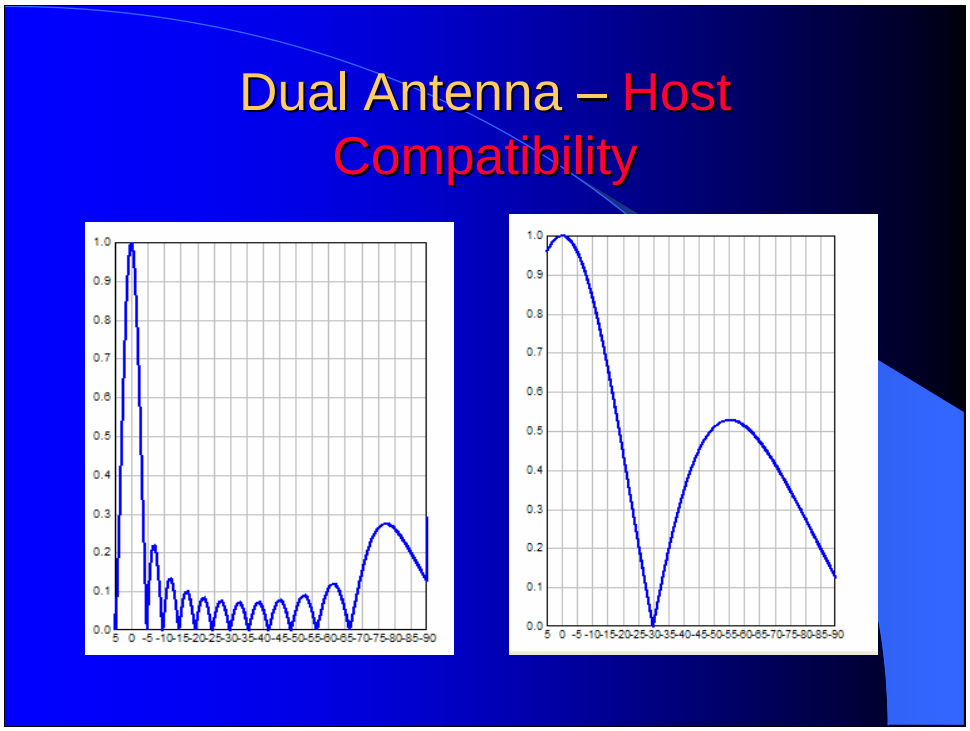
It is possible for IBOC to interfere with the host station's analog. (More on this.)



Testing by the Advanced Television Technology Center (ATTC) determined that most car radios showed no measurable change in signal to noise when IBOC was added to the host signal.

Portable radios, however, showed a reduction in signal to noise of from 3 to 12 dB.

After turning on IBOC many stations have reported that their analog air monitors exhibit white noise in the background.



Another issue relating to host compatibility is the use of dual antennas. The FCC allows a separate antenna to be used under an STA if the antenna is within 70% of the height of the primary antenna and within 3 seconds of latitude or longitude. While often a less expensive way to add IBOC to a station, the use of dual antennas can result in significant interference to the host station. For example, one station, located in a populated area of Minneapolis, turned on its IBOC using a separate antenna and was surprised to find the HD operation caused severe interference to the host analog station within a 2 mile area. Since the host station was its bread and butter the station engineers quickly turned off the IBOC, took down the antenna and moved to a high-level combined system which eliminated the interference.

Another station reported that a listener within a mile and within sight of its tower could no longer receive the station due to its own HD interference.

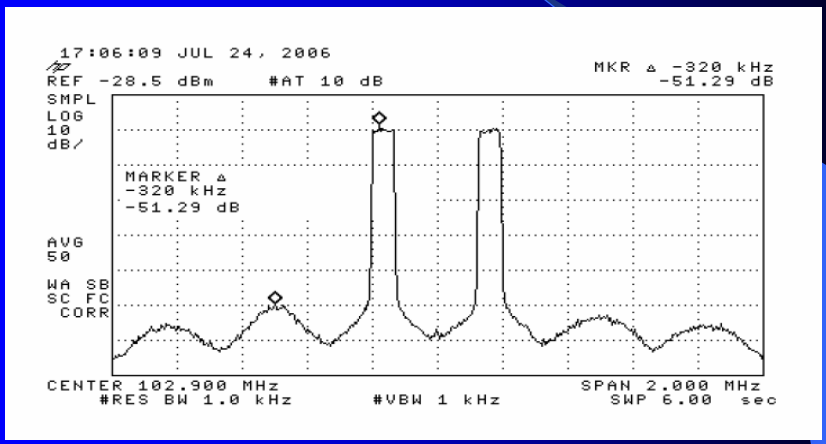
The vertical elevation field graphs shown on this slide show why. Note that these graphs are for a 12-bay main analog antenna and a two-bay IBOC antenna.

Dual Antenna IBOC Ratio @ 1000’

Angle in Degrees	Analog Field 12 bay	IBOC Field 2 bay	Distance in feet	Analog to HD Ratio
0	1	1	~	100:1
-5	0.1	0.95	11,430	1:0.9
-12	0.135	0.80	4,701	2.8:1
-27	0.075	0.5	1,963	2.3:1
-55	0.1	0.53	700	4:1

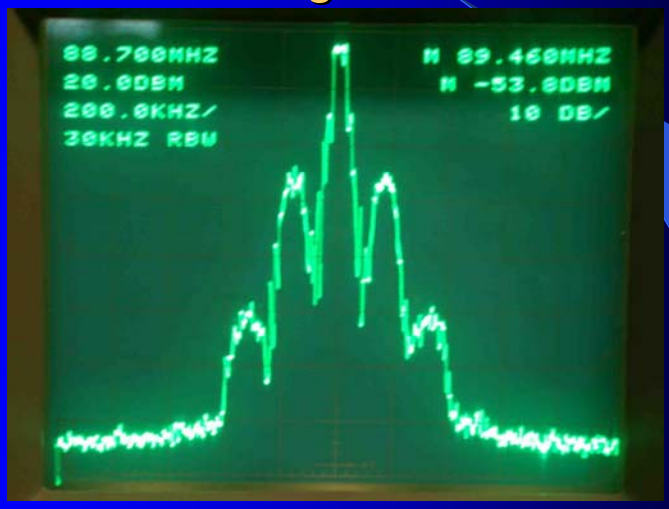
This chart shows that the IBOC 20 dBc ERP power ratio is not maintained along various vertical angles and horizontal distances from the antenna. Note that while the ratio of analog to IBOC power should be 100 to 1, this ratio was not fully obtained until the listener was in the main lobe of the 12 bay antenna. Anecdotally, NPR engineers have found that some dual antenna systems also do not perform as well at greater distances.

Interference to Other Stations
IBOC without Analog



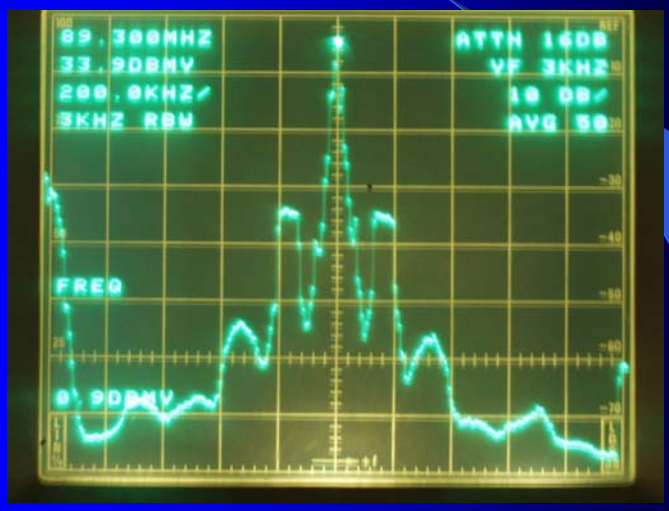
Worrying about grunge. This is a spectrum analyzer snapshot showing only the IBOC portion of the waveform. Note there is no grunge in the IBOC slopes. (Slide Courtesy of iBiquity)

Hybrid FM with Spectral Regrowth



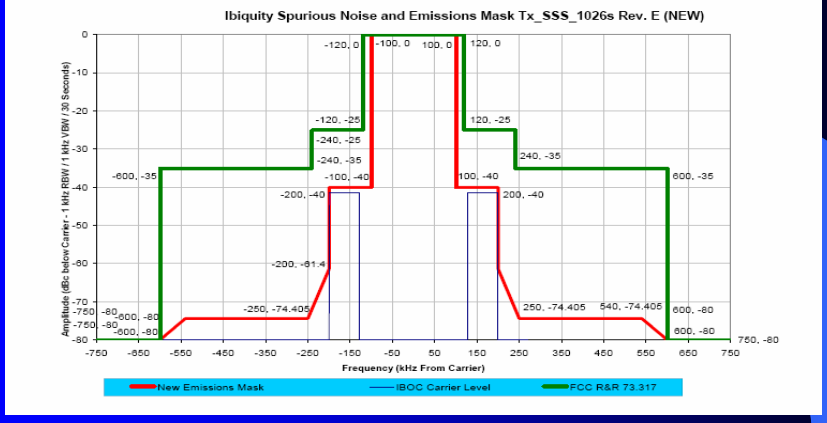
This graph is of a real station's IBOC testing. Although, this station meets the FCC's FM mask requirements, the transmitter does not meet the IBOC mask. This station caused significant 2nd adjacent interference to a distant station owned by the same company that was being monitored within 3-4 miles of the IBOC transmitter. The grunge is typically caused by non-linearity in the transmitter.

Hybrid FM with Grunge



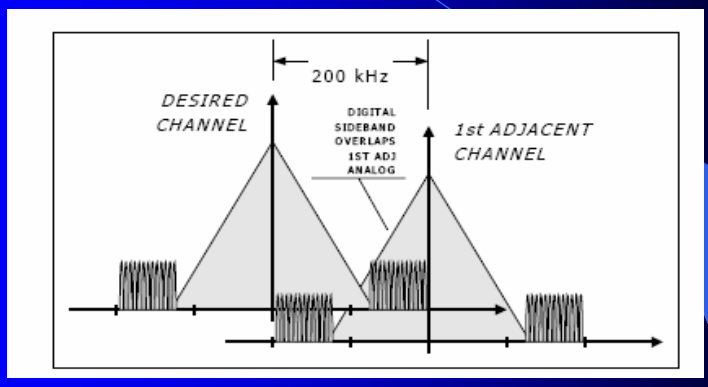
This station grunge places excessive energy on the first and second adjacent channels. When this station turned on its IBOC it wiped out several translators transmitting from the same location. The fix was an expensive output band-pass filter for the offending transmitter. 2nd generations IBOC transmitters use adaptive pre-correction which is can help correct some of the illustrated “grunge” problems, but not all.

New iBiquity Mask



This slide dhows the new iBiquity mask in red and the FCC's analog mask in green. The area of change is between +- 200 and 250 kHz. The change creates a more gentle slope (in the grunge area) that may allow more stations to meet the mask when converting to digital. However, the change also allows slightly more digital energy to be transmitted in the 1st adjacent channel, which under some conditions may be more troublesome. (Slide Courtesy of iBiquity)

Interference to other stations
First Adjacent Hybrid Interference



We can now focus on IBOC to analog interference to the first-adjacent channel. This graph, from the NRSC FM FCC filing, shows that the energy within the desired channel is overlapped by energy from the first-adjacent hybrid station. The undesired station's lower digital carrier is actually inside the desired station's main analog channel.

MOS 1st adjacent HD Interference to Analog

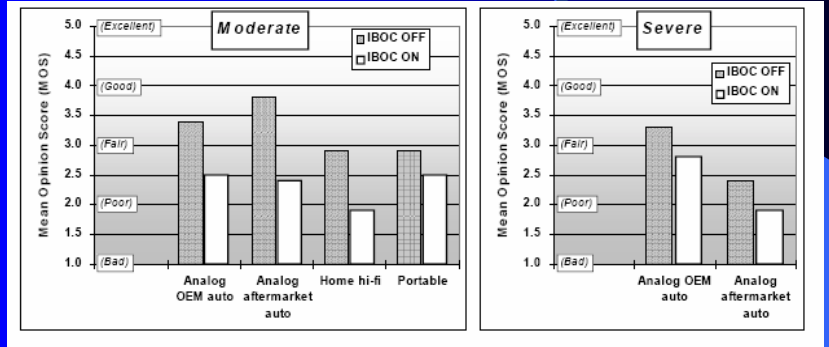
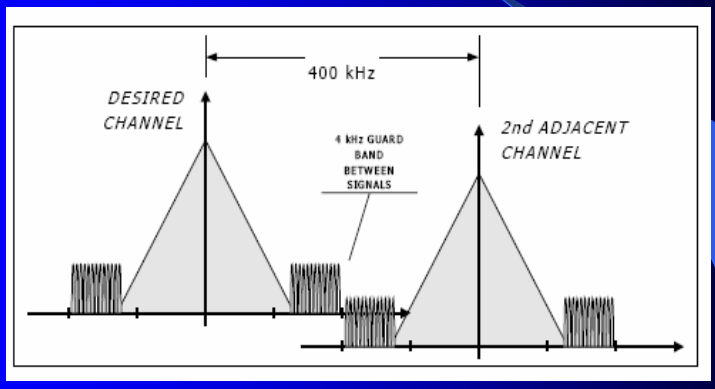


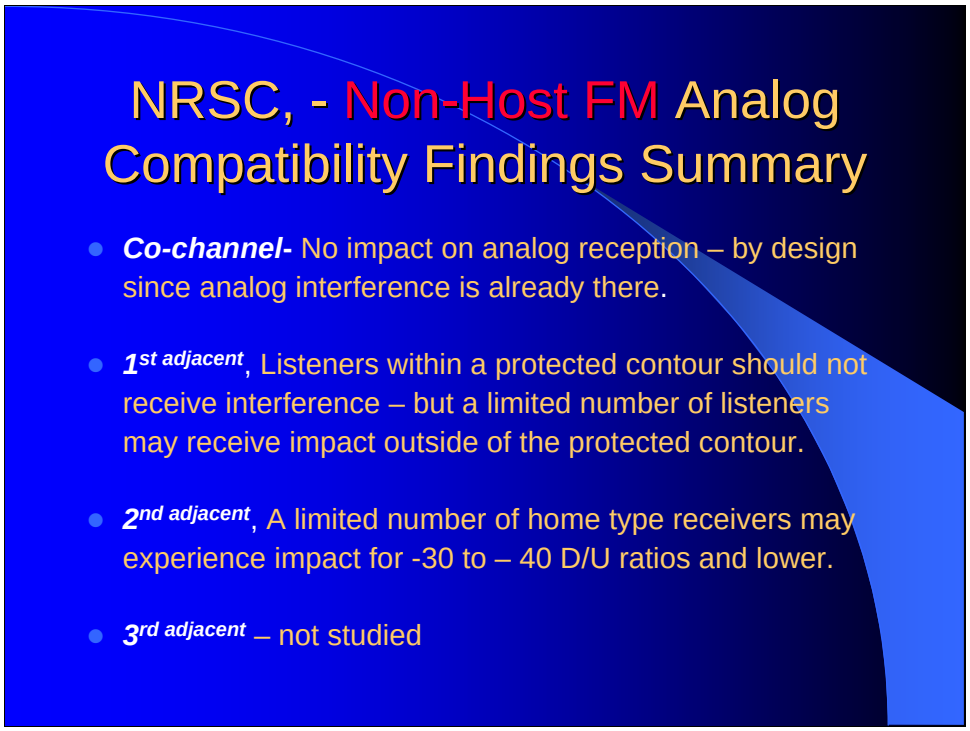
Figure 10. 1st-adjacent compatibility - subjective evaluation results of audio recordings obtained in the field (speech programming)
Moderate: +16 to +6 dB D/U
Severe: +6 to –9 dB D/U

NRSC Mean Opinion Scores (MOS) were generated by test subjects who, in the case above, were listening to speech programming with moderate interference. These listeners were exposed to analog audio without 1st adjacent HD interference and with it. The mean opinion audio quality scores are seen on the vertical axis. The white bars represent the analog audio quality with IBOC on. This shows that listeners subjectively observe a deterioration of the quality of a station's analog signal in the presence of first-adjacent hybrid interference at moderate and severe levels.

Second Adjacent Hybrid Interference



This graph shows that at 2nd adjacent, 400 kHz. there is a overlap of the HD signals within the guard-band region of the signals.



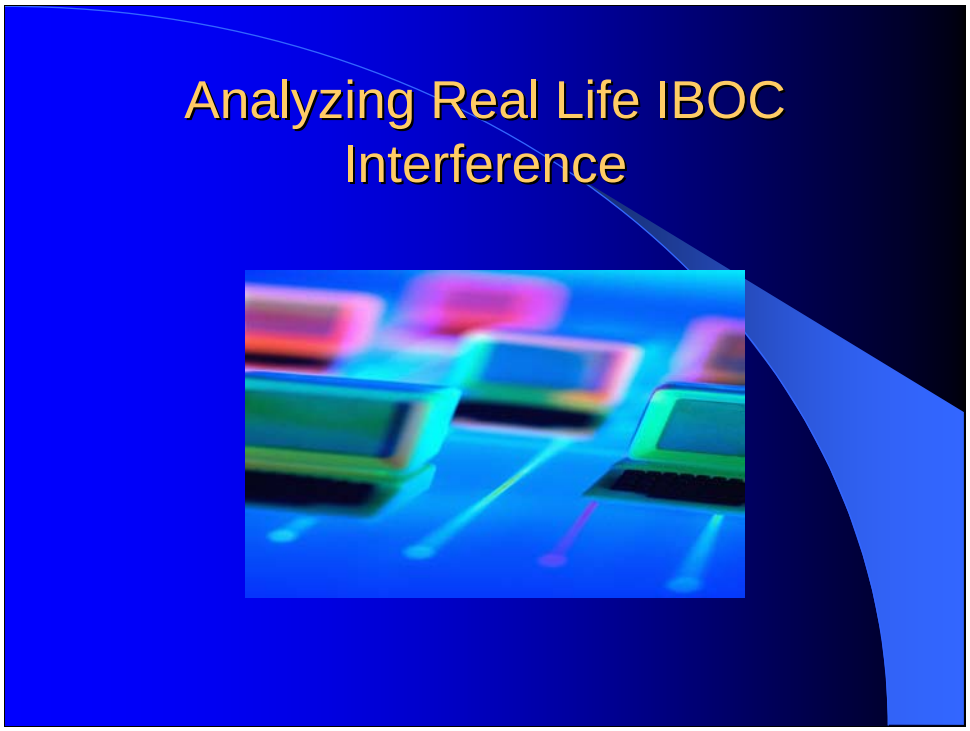
These are the NRSC non-host findings with regard to HD interference to analog stations.

•Co-channel – No impact

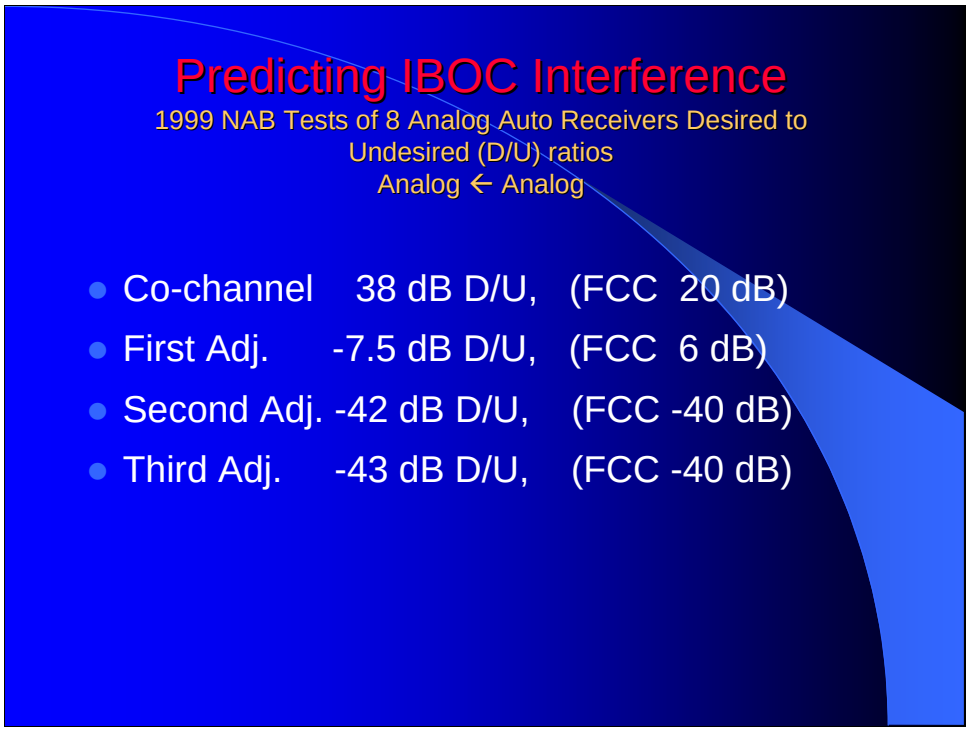
• 1st adjacent listeners within protected contour should not receive interference, however a number of radios outside the protected contour may receive interference.

• For 2nd adjacent, a limited number of home type receivers may experience interference for -30 to -40 D/U's and lower.

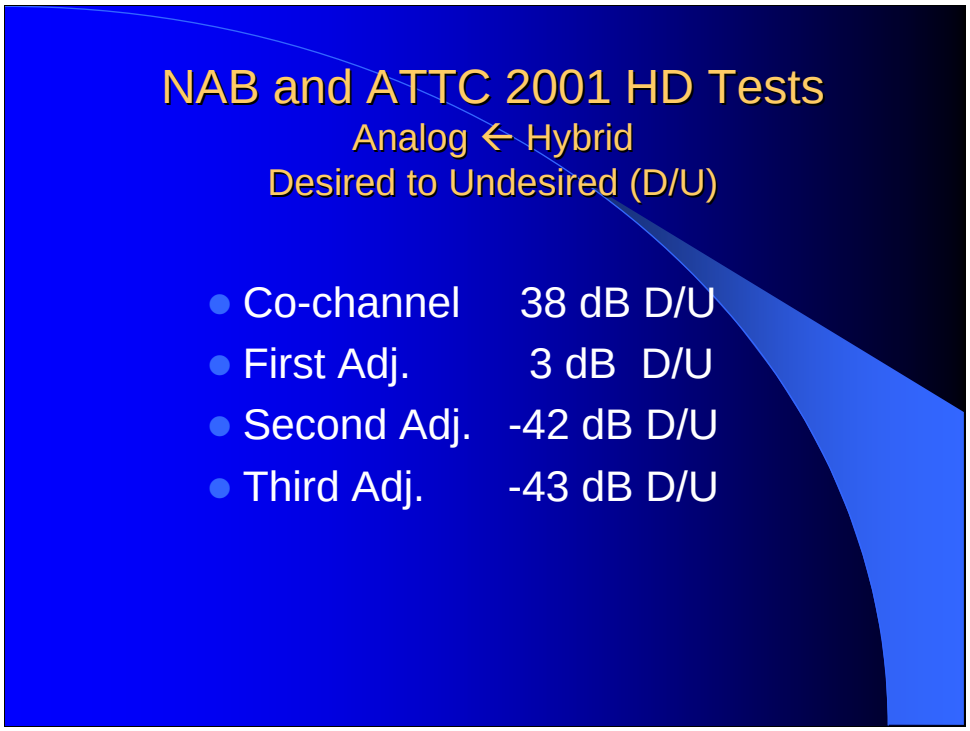
•3rd adjacent relationships were not studied and thought not to be of consequence.



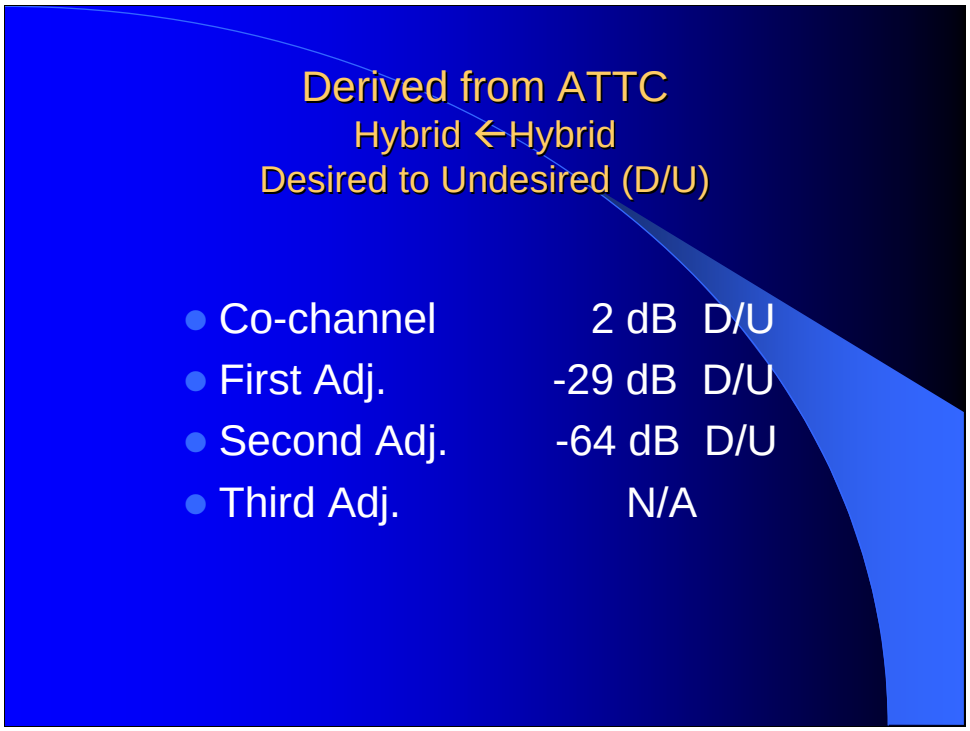
Recently, I put a post on several broadcasting related listservs requesting that people report to me any real cases of IBOC interference either caused or received. I was somewhat surprised by the volume of responses received. Due to time constraints, what follows represents only a few of the cases reported.



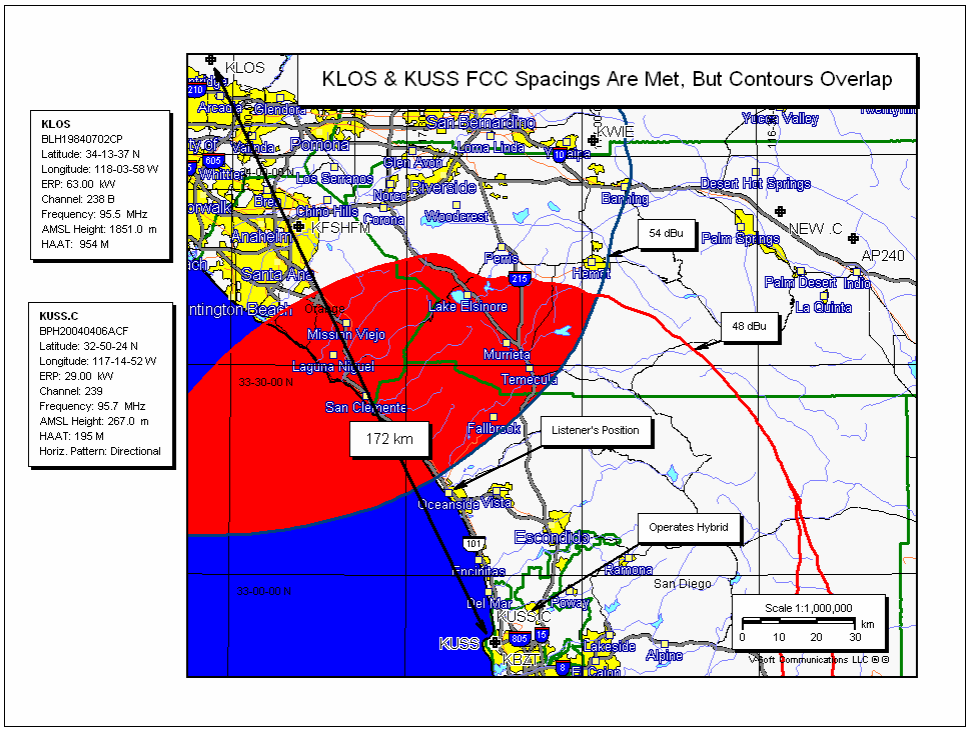
We'll take these real life examples and analyze the extent of the interference by using Longley-Rice and a prediction model based on D/U ratios gleaned from the existing receiver studies. These D/U values were set at the point where adjacent interference just becomes noticeable. (A 5 dB decrease in the signal to noise ratio.) These and the D/U ratios to follow for Hybrid into Analog and Hybrid into Hybrid were used to develop the predictions the interference predictions.



These D/U ratios for hybrid into analog were determined through NAB/ATTC testing.



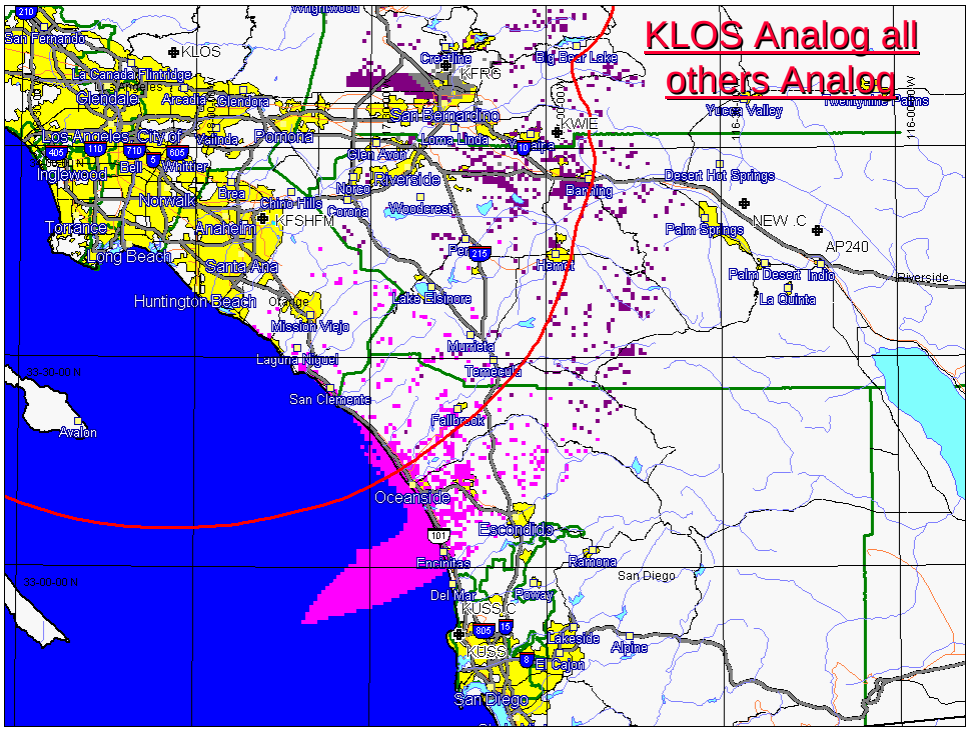
These D/U ratios for hybrid into hybrid were derived through NAB/ATTC tests and other available analysis including the work done by Sid Shumate.



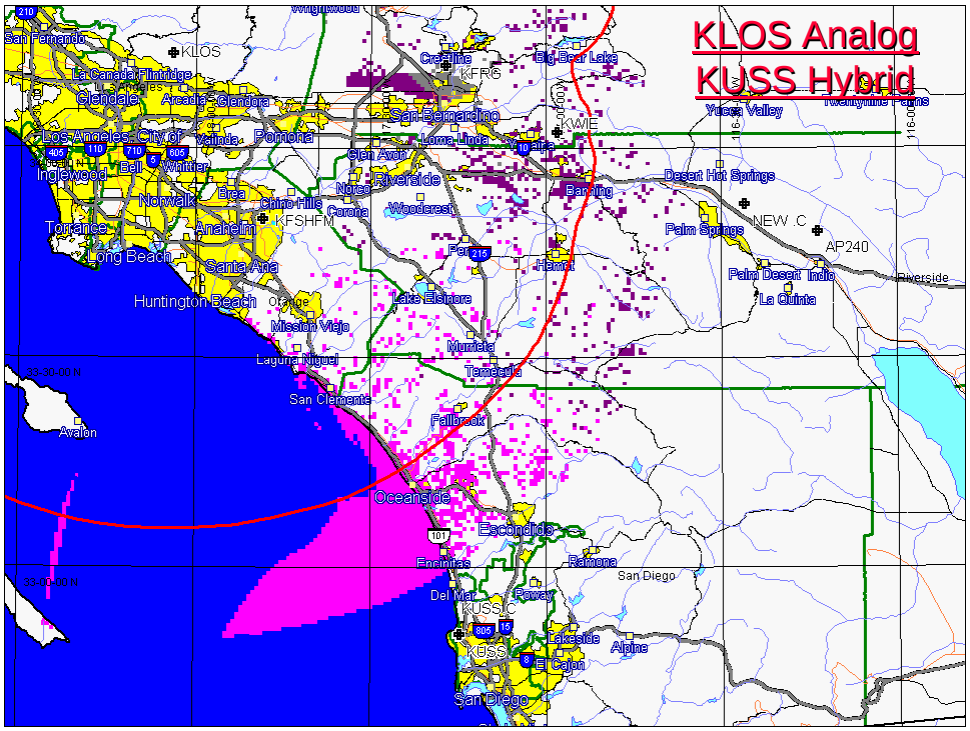
In the first case of reported IBOC interference, an Oceanside listener to LA's KLOS complained that when KUSS started transmitting with hybrid IBOC all listening to KLOS ceased in the listener's area.

In this case, there is no shortspacing between KLOS and KUSS. The FCC minimum spacings rules say that KUSS and KLOS must be at least 169 kilometers apart, when, in fact, the distance between the stations is nearly 172 km.

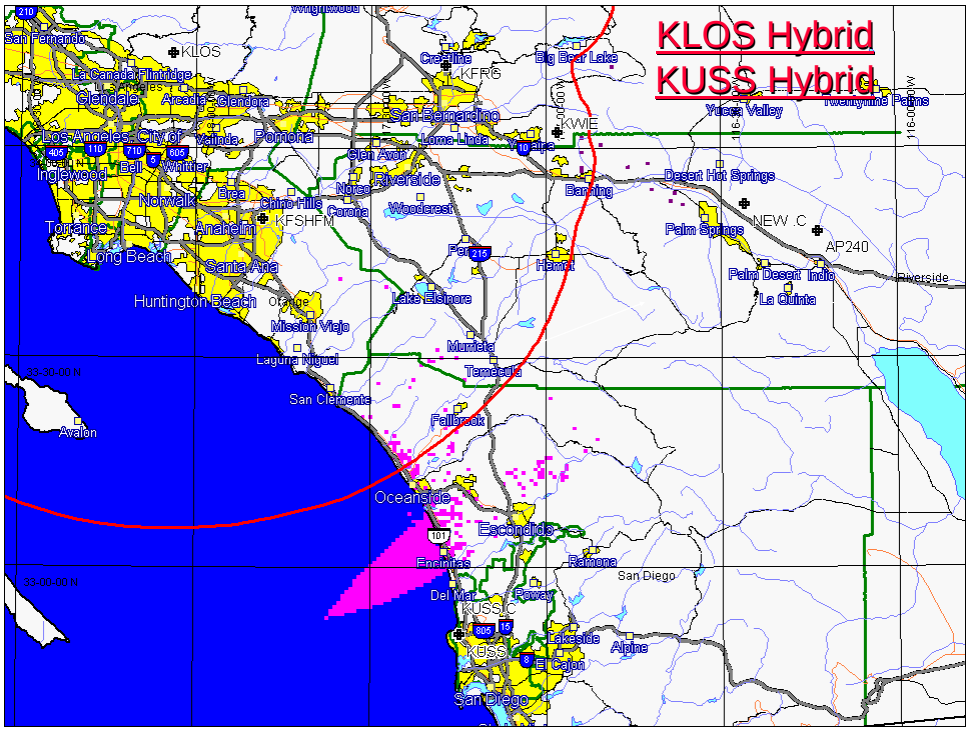
Yet, because of favorable terrain and KLOS being grandfather as an over powered class B, the actual interference and protected coverage signal contours are overlapped. In addition to this case, there are many cases of stations in the FCC database that meet the minimum FCC spacings, but that do not have contour overlap clearance. So, even without being short spaced, if the protected and interfering contours of two stations overlap, IBOC interference to analog is likely to be caused.



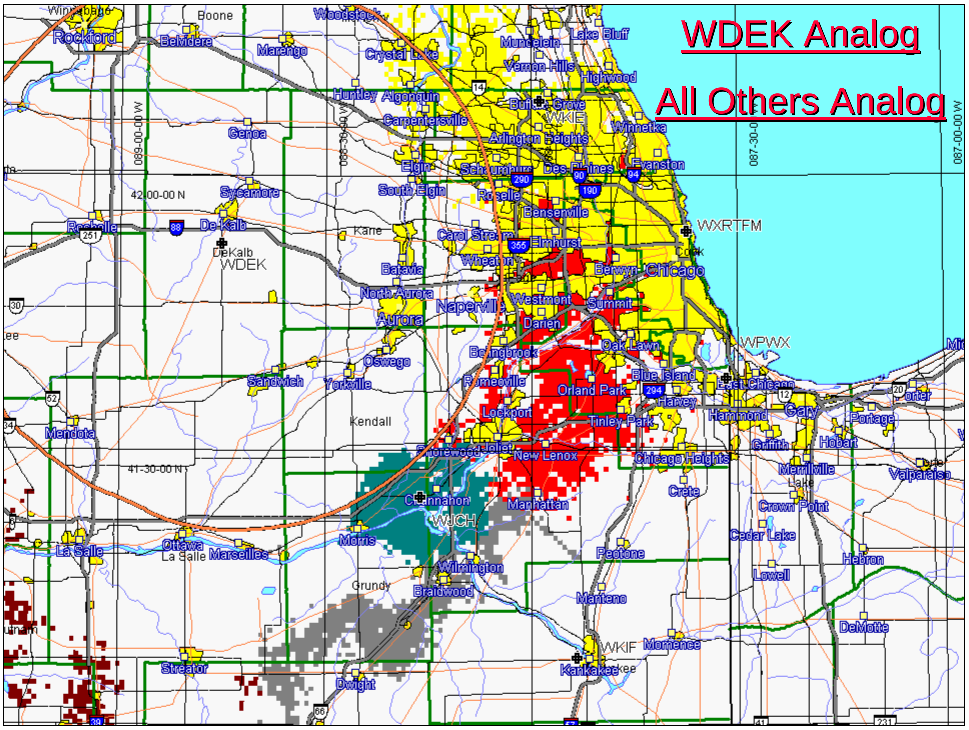
KLOS Is transmitting in Analog --- all others are also Analog. Interference area in violet is caused by KUSS operating analog.



KLOS is in analog and KUSS is being shown with its hybrid operation. Notice the additional interference within the KLOS protected 54 dBu contour… and particularly the new interference up the coast.

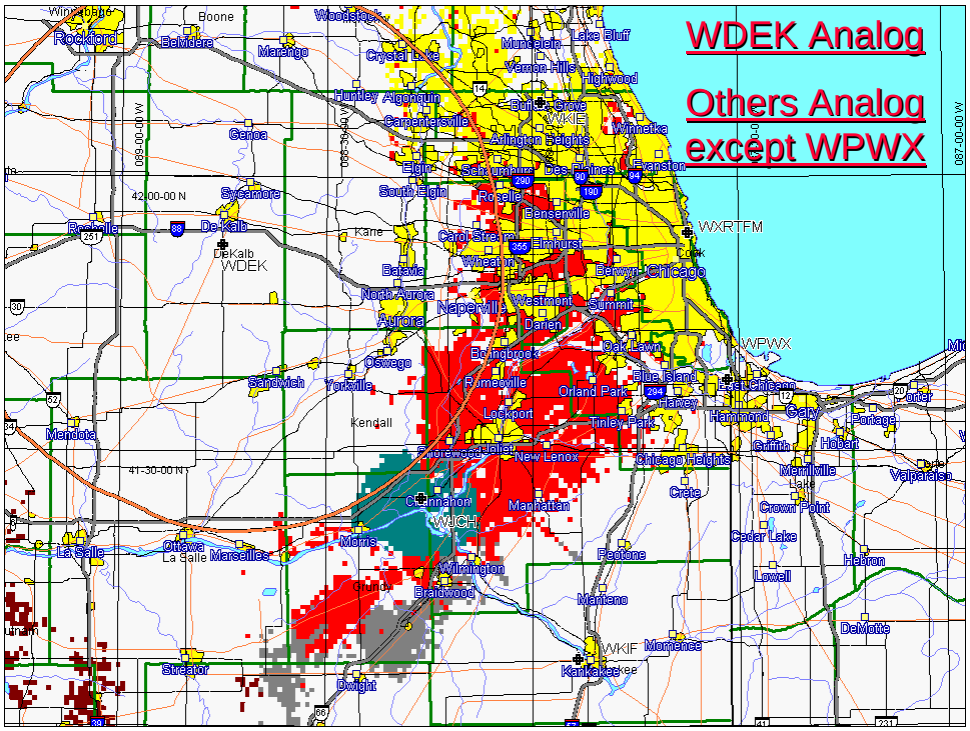


KLOS Is transmitting in Hybrid --- KUSS is hybrid. We are looking at IBOC reception. The interference area is caused by KUSS operating in the hybrid mode. Note that digital to digital interference is much less than all other interference varieties.

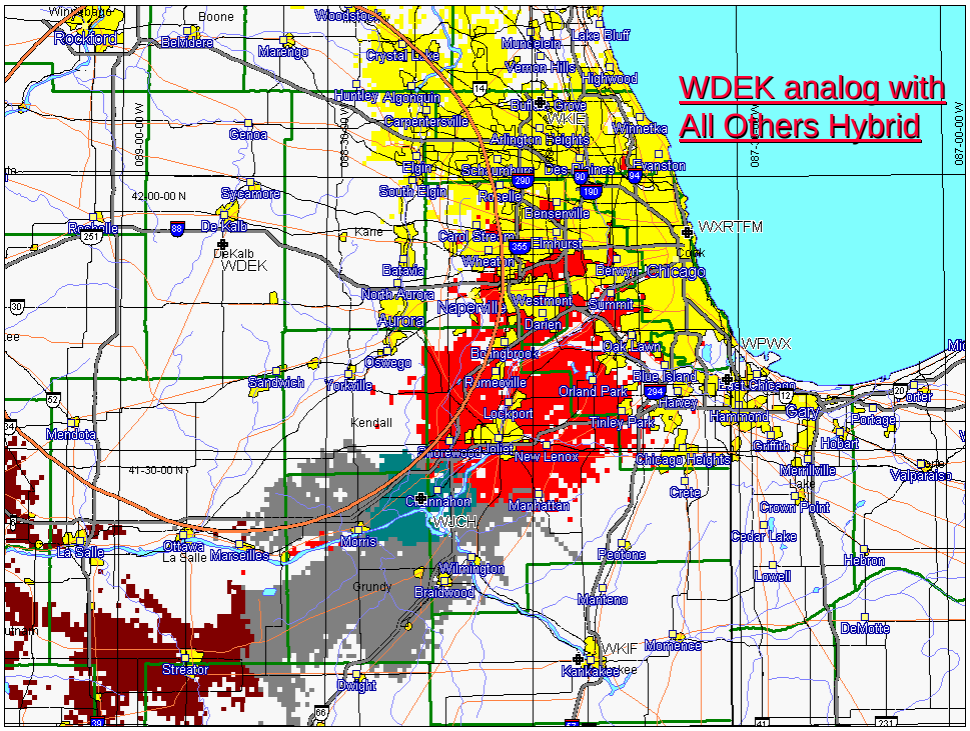


In this case of reported IBOC interference, we find that the 1st adjacent class B stations, WDEK and WPWX are short spaced. WDEK receives IBOC interference from WPWX. On its 1st adjacent, WPWX should be 169 kilometers apart from WDEK, but it's only 105.6 kilometers from WDEK. WPWX operates with a directional antenna to protect WDEK, but, even so, the FCC protected and interference contours cross significantly.

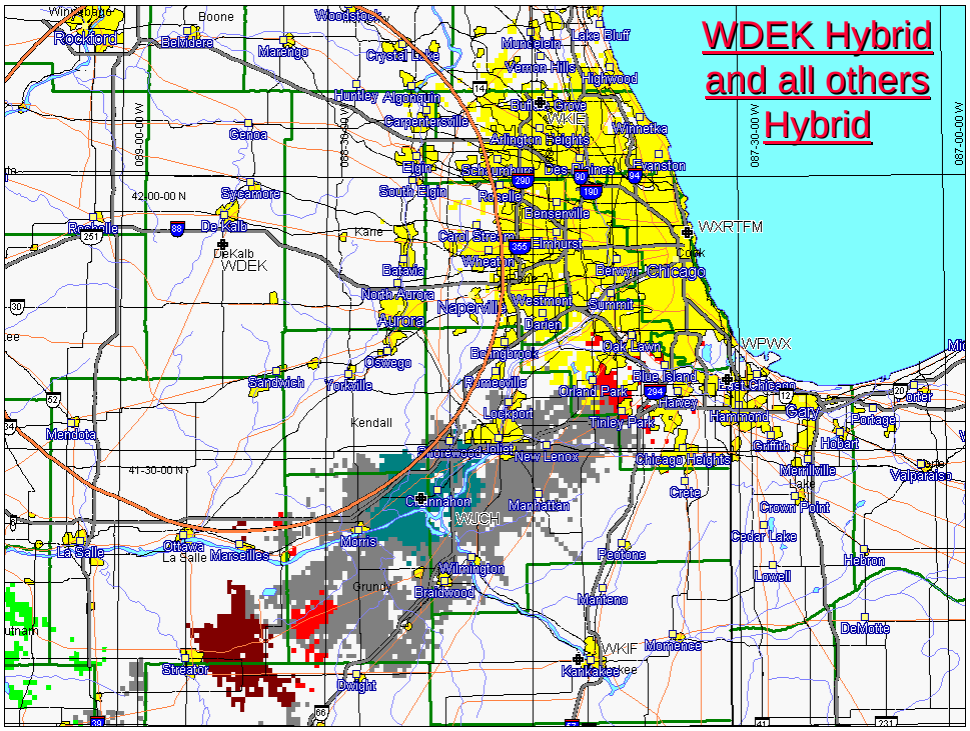
On this map we're looking at a plot of interference. WDEK and all the surrounding stations are operating in the analog mode, so this is a before IBOC picture.



Here WDEK operates in analog and all the other stations operate in analog except for WPWX that operates in hybrid digital. The interference area is increased to WDEK including areas within its protected 54 dBu contour.

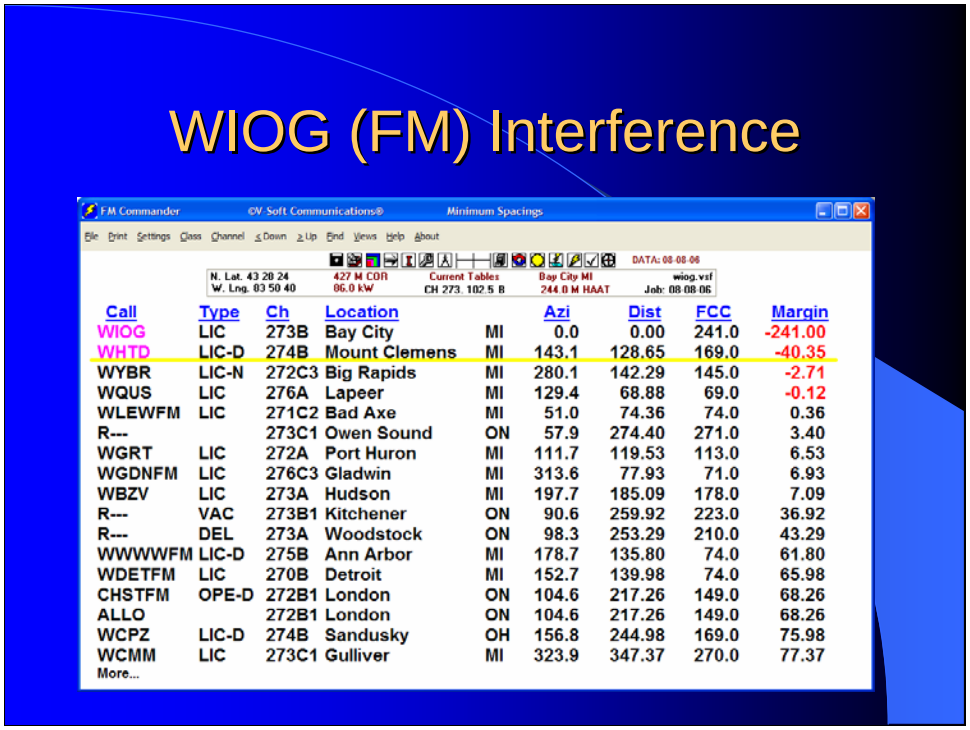


Here WDEK operates in analog and all the other stations operate in hybrid. This slide represents the most interference to WDEK.



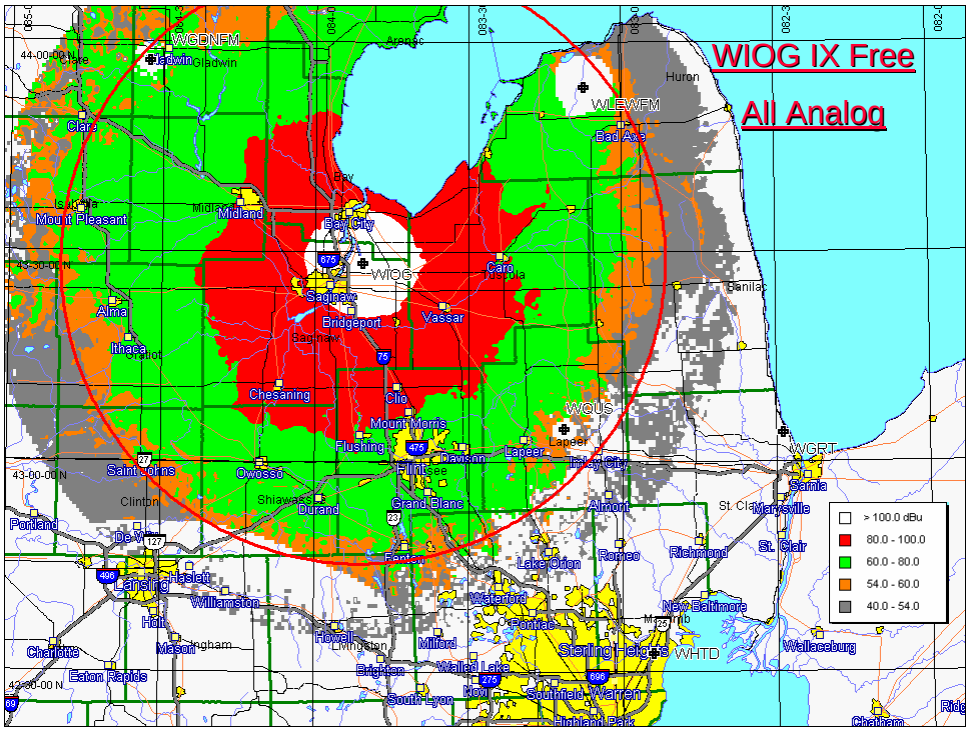
This final map shows all stations operating in hybrid digital including WDEK.

WIOG (FM) Interference

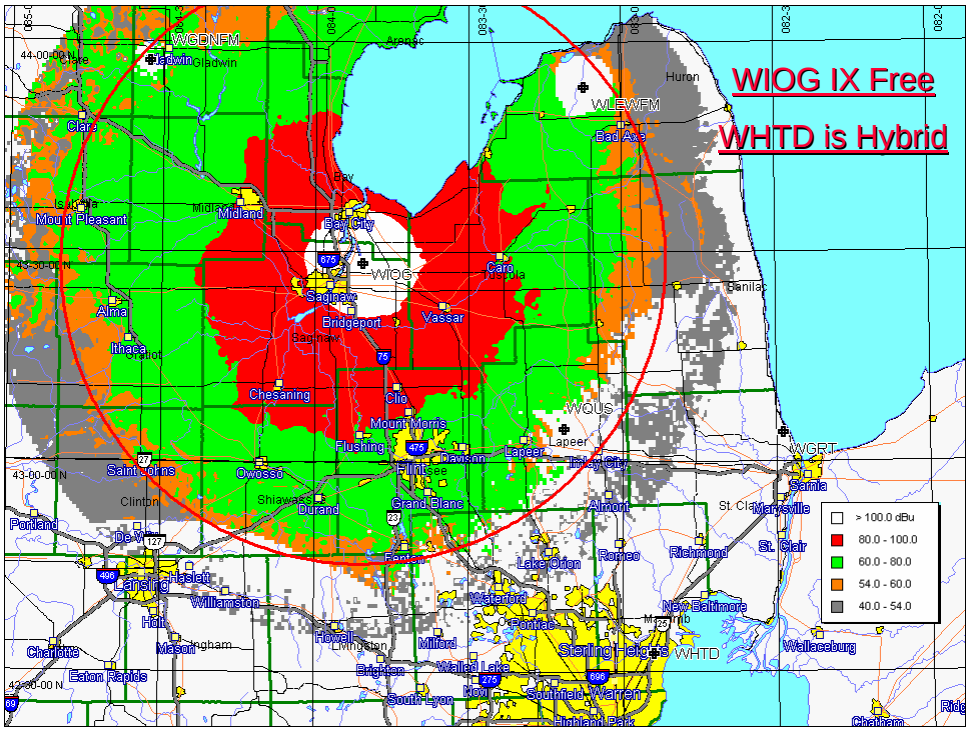


Call	Type	Ch	Location		Azi	Dist	FCC	Margin
WIOG	LIC	273B	Bay City	MI	0.0	0.00	241.0	-241.00
WHTD	LIC-D	274B	Mount Clemens	MI	143.1	128.65	169.0	-40.35
WYBR	LIC-N	272C3	Big Rapids	MI	280.1	142.29	145.0	-2.71
WQUS	LIC	276A	Lapeer	MI	129.4	68.88	69.0	-0.12
WLEWFM	LIC	271C2	Bad Axe	MI	51.0	74.36	74.0	0.36
R---		273C1	Owen Sound	ON	57.9	274.40	271.0	3.40
WGRT	LIC	272A	Port Huron	MI	111.7	119.53	113.0	6.53
WGDNFM	LIC	276C3	Gladwin	MI	313.6	77.93	71.0	6.93
WBZV	LIC	273A	Hudson	MI	197.7	185.09	178.0	7.09
R---	VAC	273B1	Kitchener	ON	90.6	259.92	223.0	36.92
R---	DEL	273A	Woodstock	ON	98.3	253.29	210.0	43.29
WWWWFM	LIC-D	275B	Ann Arbor	MI	178.7	135.80	74.0	61.80
WDETFM	LIC	270B	Detroit	MI	152.7	139.98	74.0	65.98
CHSTFM	OPE-D	272B1	London	ON	104.6	217.26	149.0	68.26
ALLO		272B1	London	ON	104.6	217.26	149.0	68.26
WCPZ	LIC-D	274B	Sandusky	OH	156.8	244.98	169.0	75.98
WCMM	LIC	273C1	Gulliver	MI	323.9	347.37	270.0	77.37

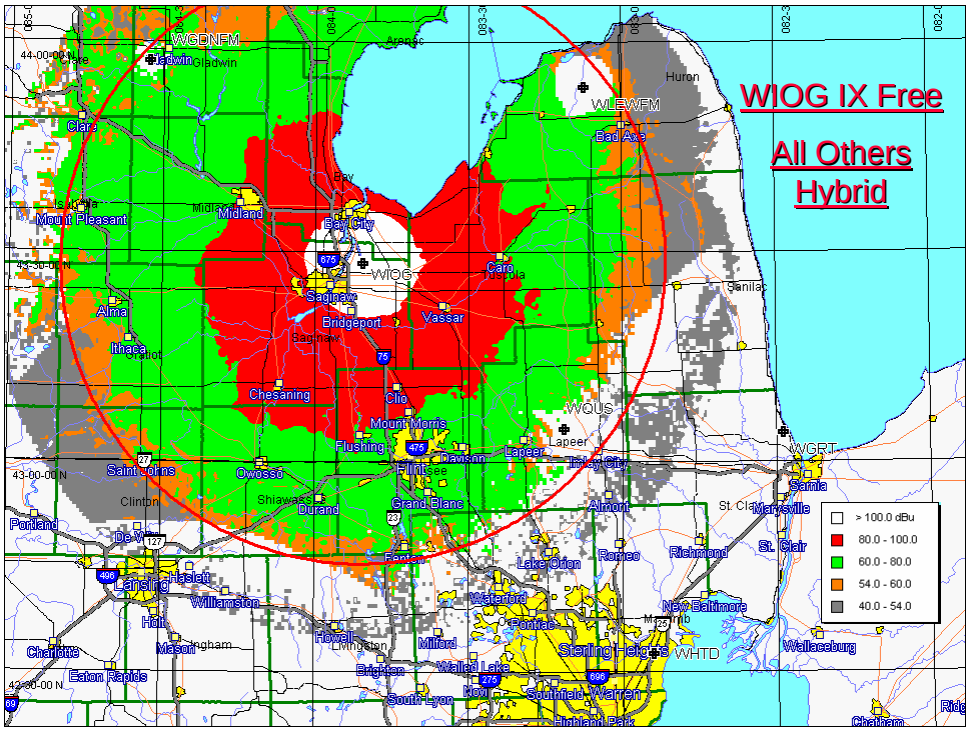
WIOG is shortsapaced with 1st adjacent WHTD. Both stations are class B FM stations. The FCC requires a 169 km separations between these stations, but there is only 128.7 km available. The FCC has given the stations a waiver to operate in this fashion, (probably grandfathered.)



These are interference-free coverage maps. WIOG's interference-free coverage is shown with WIOG and all surrounding stations operating in analog.



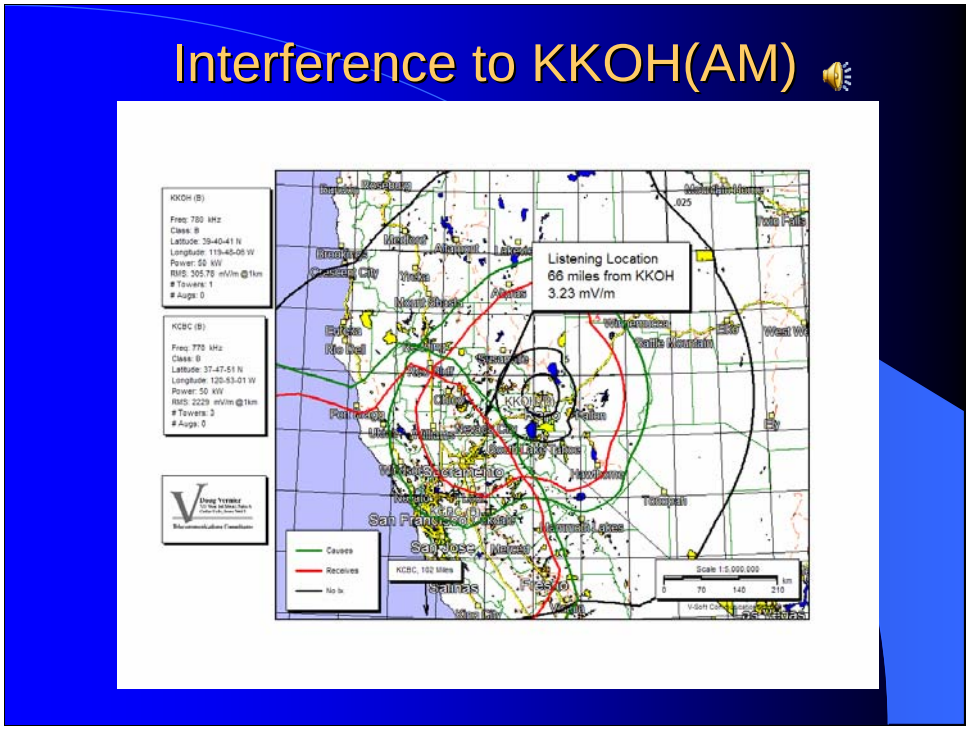
Another interference-free coverage map showing WIOG coverage when WIOG operates in analog and WHTD operates in Hybrid.



This map shows WIOG's interference-free analog coverage with all other stations operating in hybrid.

Some Examples of IBOC AM Interference

Now let’s focus on AM IBOC.



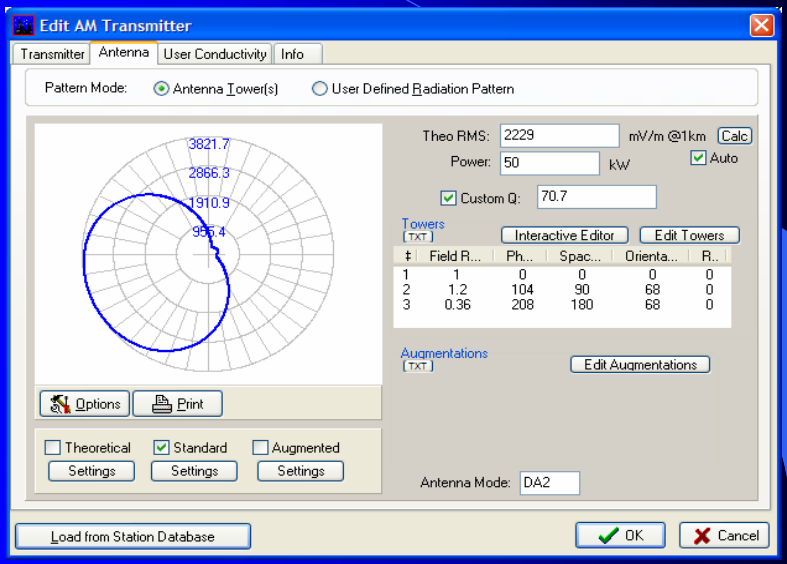
In this slide, it was reported by David Hershberger in Nevada City, California that 1st adjacent KCBC, Riverbank, CA causes serious IBOC interference to KKOH at David's location in Nevada City. From the map shown above you can see that Nevada City is well within the KKOH protected contour. Based on the M3, there is contour overlap between KKOH and KCBC. KCBC was likely granted its 50 kW by doing actual field measurements to show that the overlap did not really exist.

KCBC operates in the day-time with its 3-dower array having its null pointed directly at KKOH to provide protection.

David sent a tape to let us all listen to what KKOH sounds like from his location inside the station's 3.23 mV/m contour.

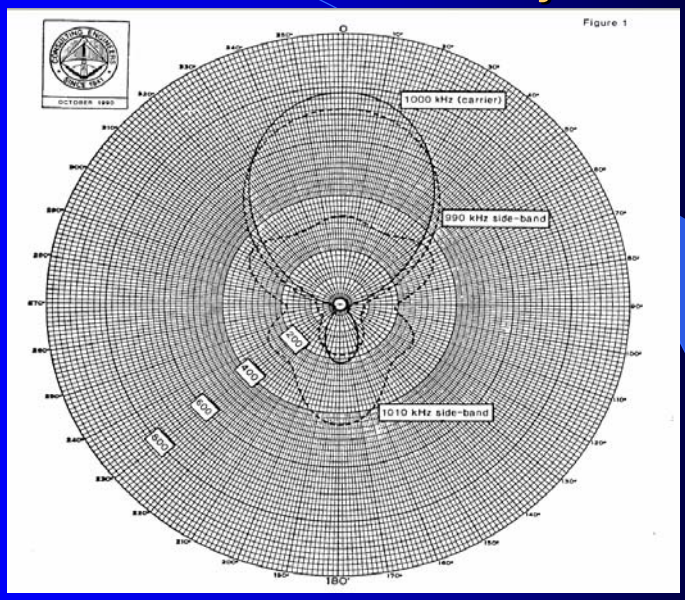
(Click speaker icon on slide to hear tape of received IBOC interference.)

KCBC's Directional Pattern



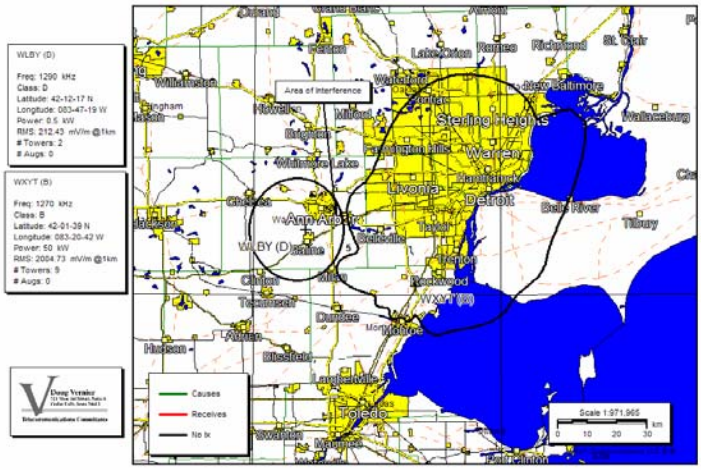
KCBC's directional pattern has a null oriented directly at KKOH.

AM Patterns Co & adjacent



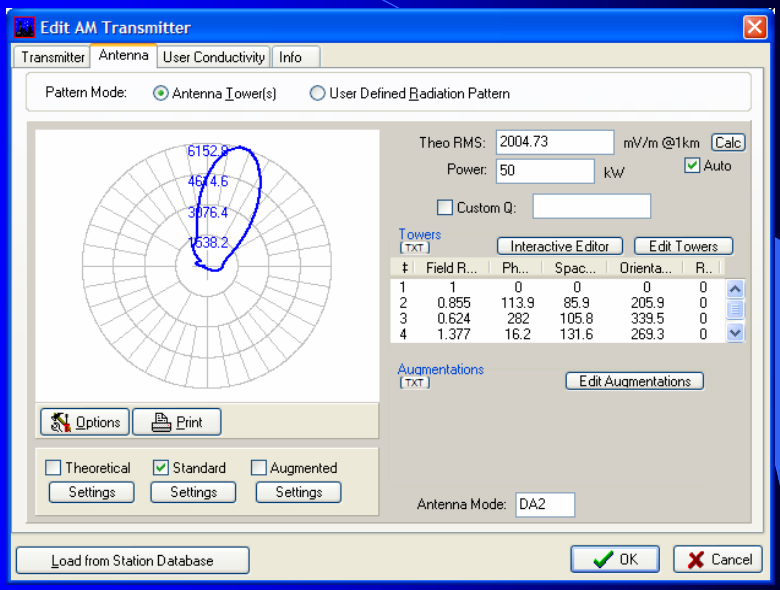
This slide, courtesy of Ron Rackley, shows three AM station patterns for the same station assigned to 1000 kHz. Note that, due to pattern bandwidth issues, the patterns are different, especially the pattern for the system on 1010 kHz, which shows a large lobe off the back of the array. So, it is very possible that a given station's protection toward an adjacent station will fall apart on the adjacent channels as is shown above.

WLBY(AM) Interference



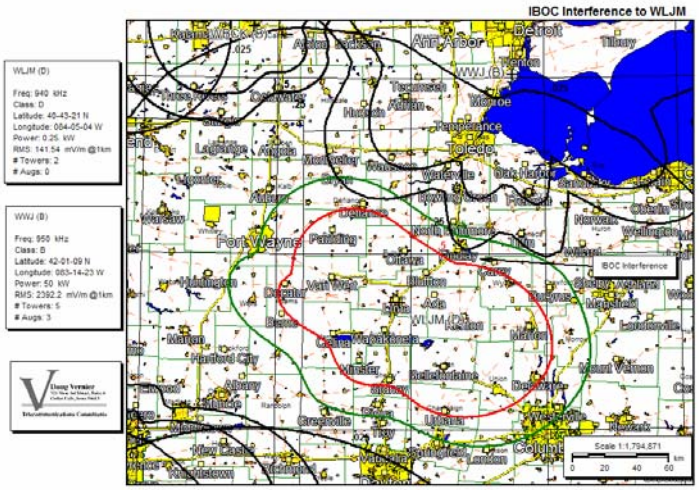
Here ***2nd adjacent*** interference is being caused by Detroit hybrid station WXYT. The reported interference is within the 5 mV/m (local signal) of WLBY in Ann Arbor.

WXYT (AM) Pattern



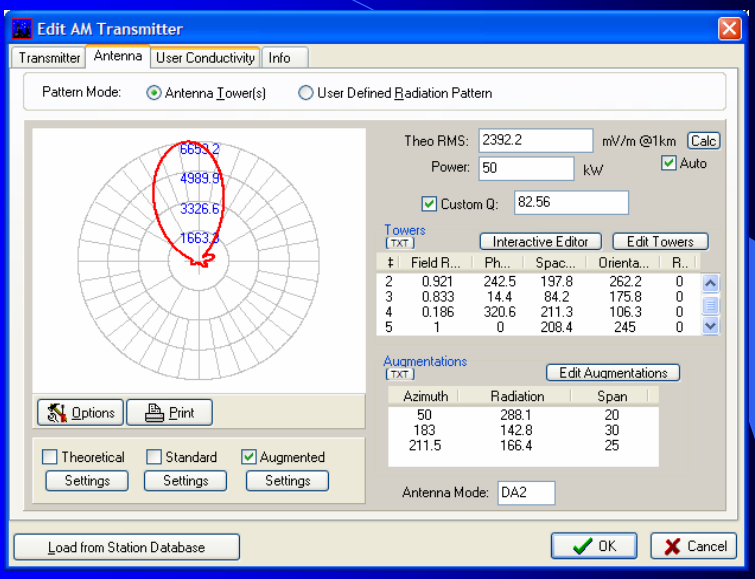
The WXYT pattern shows that WXYT is supposed to have a deep null toward WLBY.

WLJM(AM) Interference

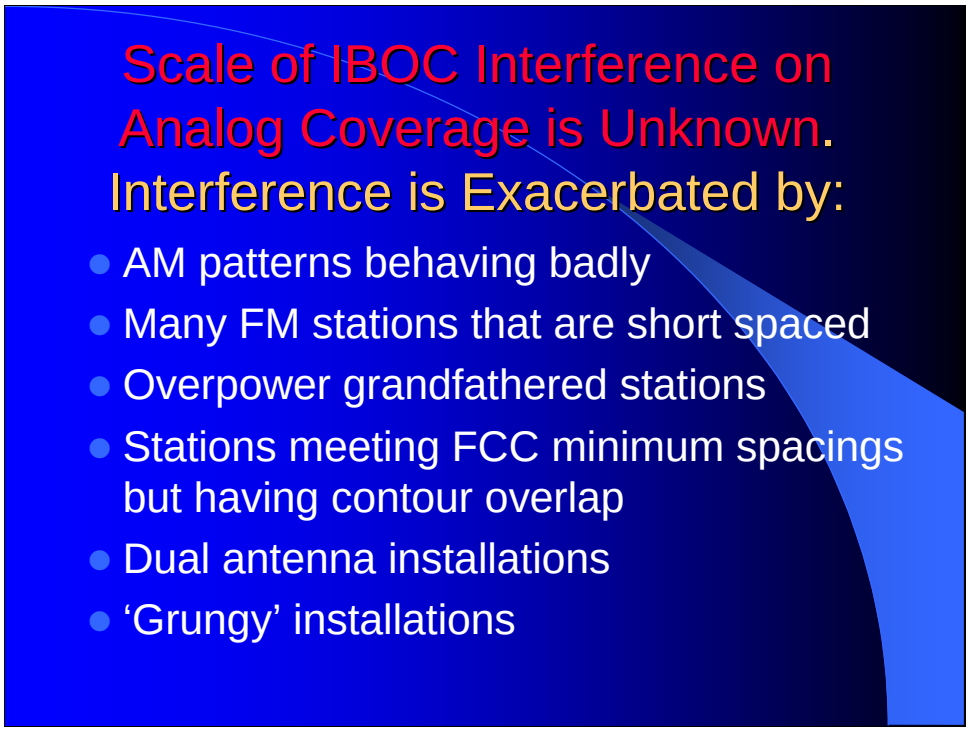


In this case, WLJM, Lima, Ohio receives IBOC interference from 1st adjacent WWJ off the back of WWJ's 5 Tower array. Where WLJM could be heard clearly in Findley now there is interference.

WWJ's Directional Pattern



This is the WWJ-AM pattern; notice that WLJM's direction is within the null side of the pattern.



We're seeing only portion of the stations taking the air now with IBOC. The long term impact on coverage is still unknown. We do know that analog station coverage is reduced by the following:

AM patterns behaving badly

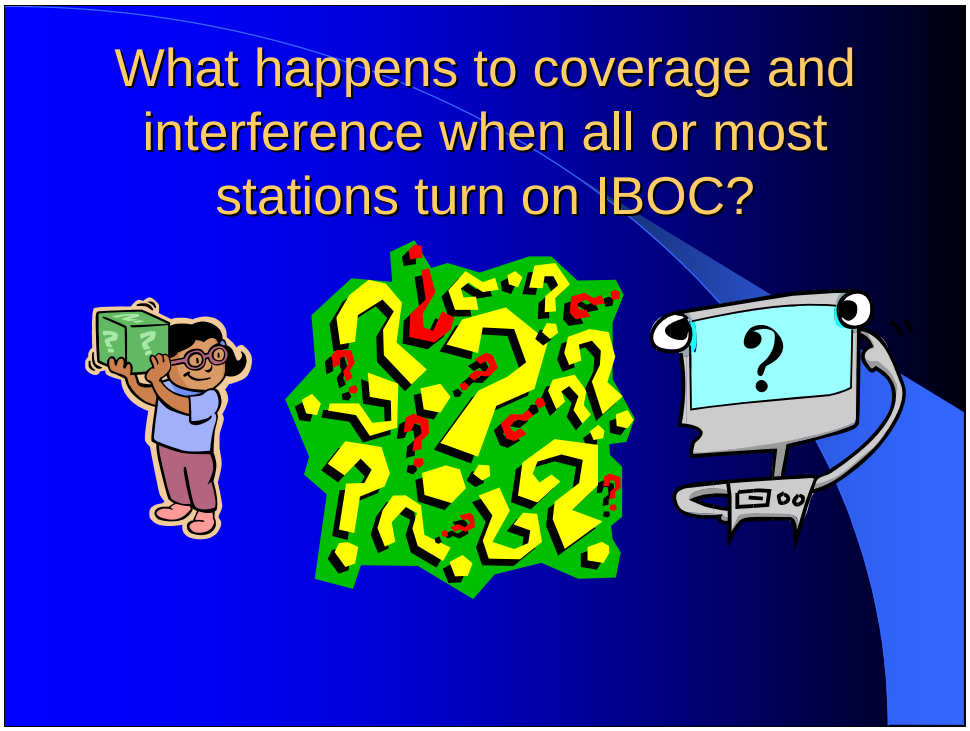
FM shortspaced stations

Overpower Grandfathered Stations

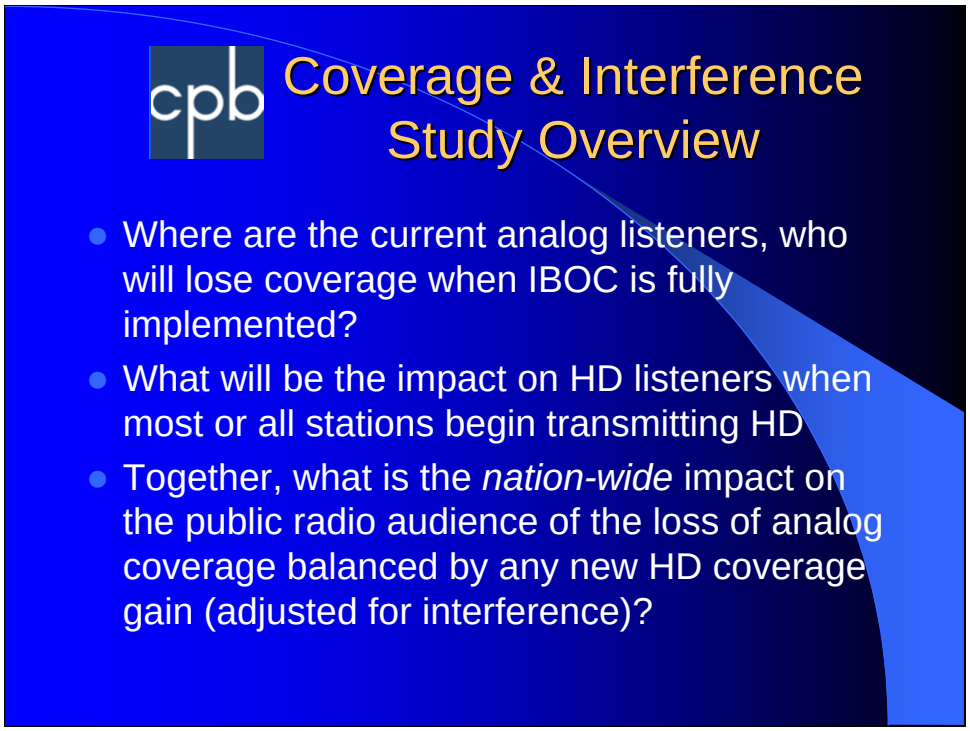
Stations meeting FCC minimum spacings but having contour overlap

Dual antenna installations

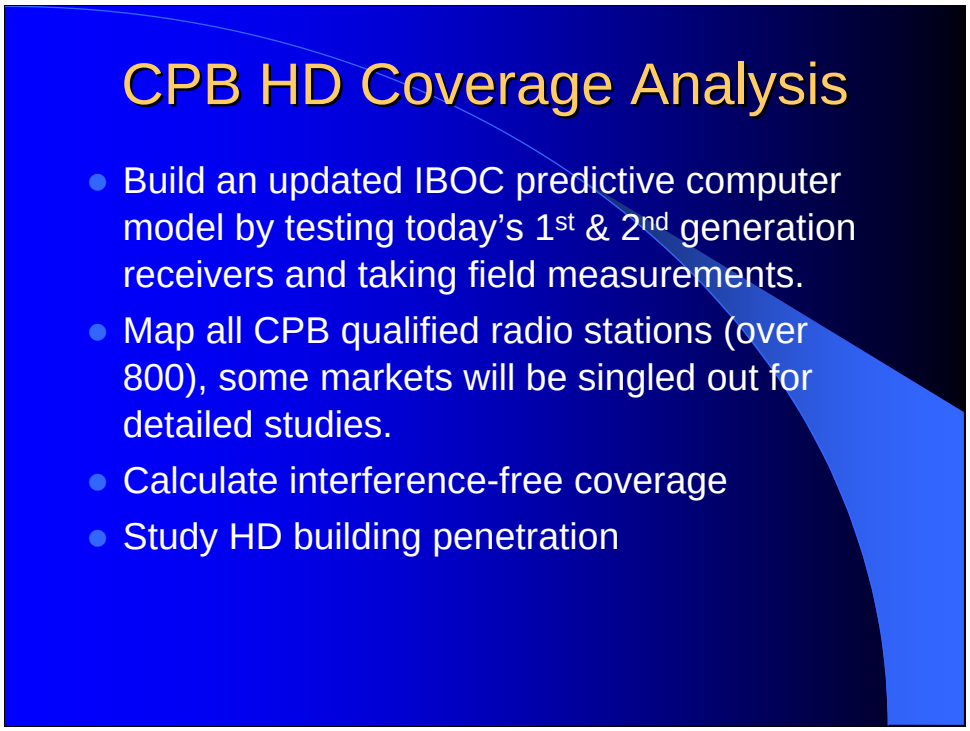
'Grungy' installations



So, what happens to coverage and interference when all or most stations turn on IBOC?



The Corporation for Public Broadcasting is undertaking a program to find out how IBOC interference to existing analog stations and new HD stations will cumulate.



Specifically the CPB Coverage Analysis will..

•Build a Predictive Computer Model specifically designed to handle IBOC coverage and Interference.

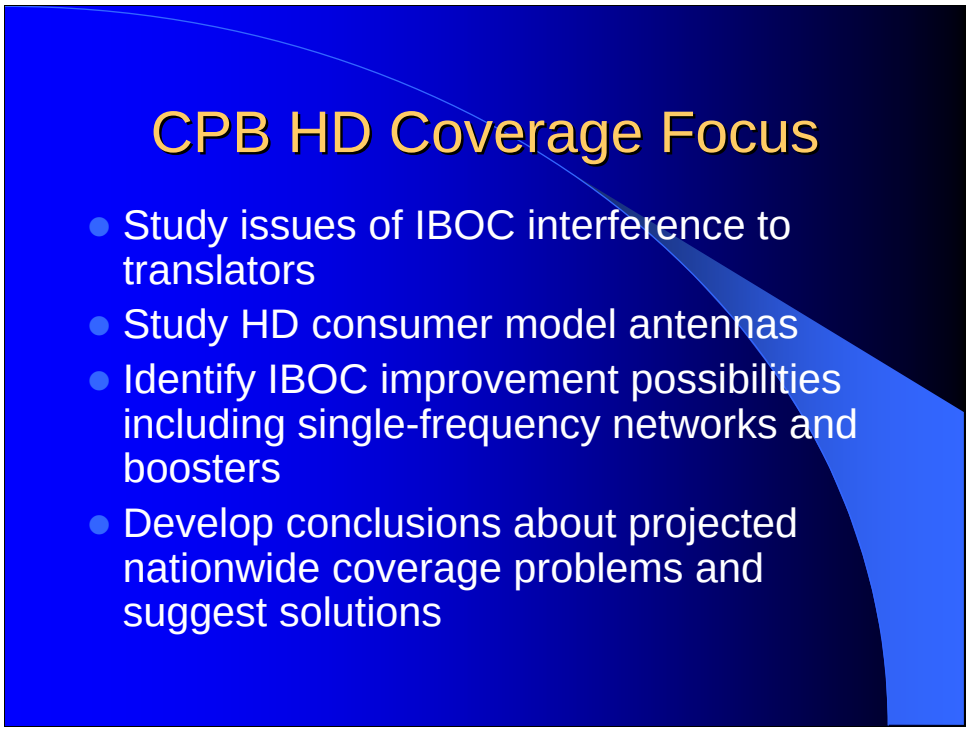
•Define coverage by testing today's receivers and by taking field measurements

• Study and map all CPB qualified radio stations (over 800), select 25 of the largest market stations for detailed studies (50-66 dBu areas).

• Generate Detailed studies of 25 smaller market 'rim-shot' stations

• Define coverage by subtracting interference areas.

• Study HD building penetration



The analysis will also:

- Study the impact of IBOC interference on translators and boosters
- Study portable, table model and auto HD radios
- Study HD consumer model antennas
- Identify IBOC improvement possibilities including single-frequency networks and boosters
- Develop conclusions about projected coverage problems and suggest solutions.

Finally, (if there is enough time), I have a tape where KCBC causes IBOC interference to KKOH. You will hear some fading in this tape. At sunset KCBC turns off its IBOC. Remember this is interference cause within KKOH's protected contour at ~ 3.2 mV/m.