

The looming danger of host interference with -10 dBc IBOC injection.

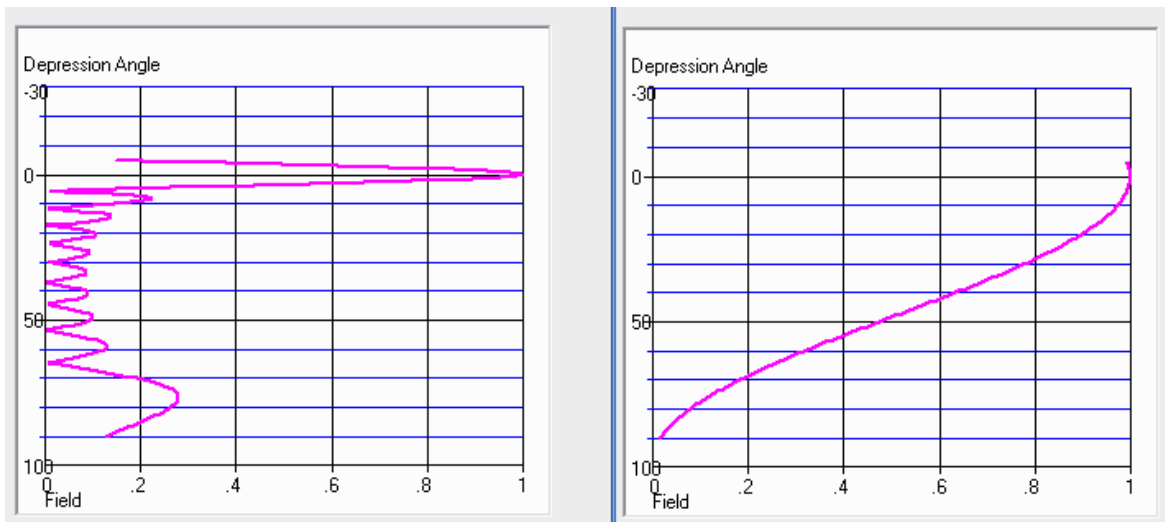
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Least considered among the ways that IBOC can affect analog FM broadcast is the issue of host interference. There has been little or no recent research that effectively explores interference to the hosting station caused by its IBOC transmissions.

Of the early tests of host compatibility, the most notable were performed by the ad Hoc NAB study group led by engineering consultant Al Rosner. Among their conclusions was one that warned that if dual antennas were used interference to the host station could result if the antenna vertical field patterns were not well matched, however the problem areas were close to the tower such that this self-interference should not be a problem. The FCC took this as their lead to allow licensed auxiliary antennas to be used for IBOC as long as the antennas the radiation center of the IBOC antenna was at least 70% of the height of the analog antenna and no more than 3 seconds of longitude and latitude separated the antennas¹.

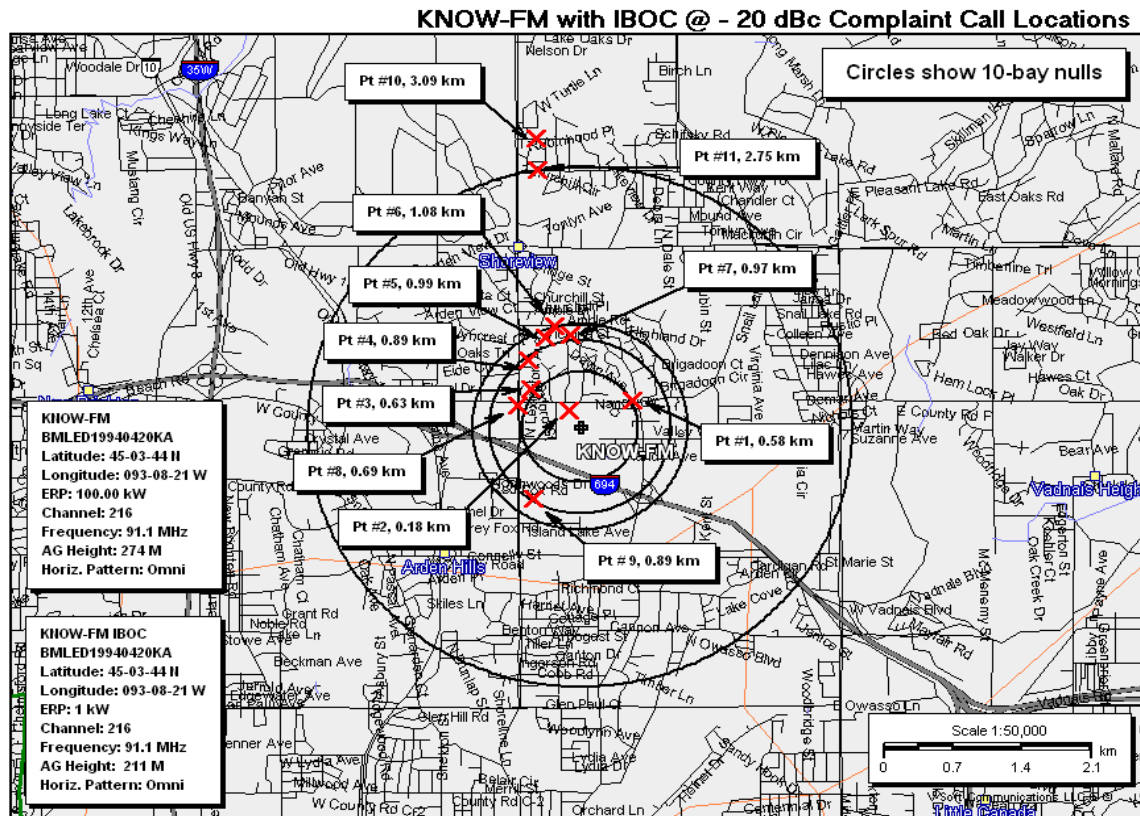
Using dual antennas for hybrid IBOC can be done at a relatively low cost when compared to other combining methods. Separate antennas are inherently more efficient because there is no power lost in a combiner where 90% of the digital signal can be shunted to ground. However, better methods exist that cause little or no host interference, such as common amplification or high level combining. Typical methods to reach the -10 dBc IBOC power level are expensive and require significantly larger transmitters, so, when (and if) higher IBOC power levels are authorized, we should expect that many stations will chose dual antennas. However, broadcasters who choose to use dual antennas should carefully evaluate the extent of host interference that their primary analog service will receive.

¹ See Section 73.404 of the FCC rules



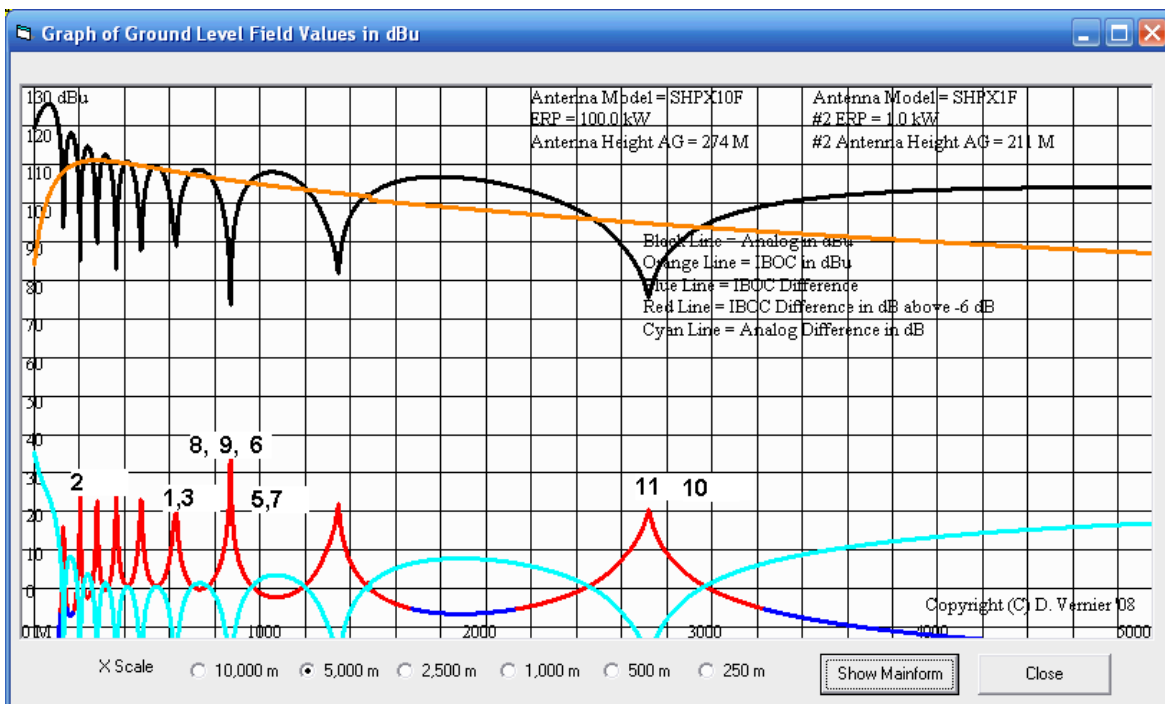
An excellent case study in host interference was presented by Mike Hendrickson of Minnesota Public Radio's KNOW in the October 2007 issue of Engineering Extra. KNOW's 10-bay antenna is located on a tower in a highly populated urban area of Minneapolis. It was cost effective for MPR to use its single bay auxiliary antenna that was already on the tower. This antenna met the FCC's minimum separation standard by having a radiation center that was within 77% of the KNOW analog antenna. The 10-bay and 1-bay vertical elevation field graphs for these antennas are shown in Figure #1.

Unfortunately, when MPR turned on IBOC at the authorized -20 dBc power level, they began receiving numerous listener complaints. They carefully documented the location of the complaints which were plotted on the map in Figure #2. The interference was reported to be quite severe, as listeners in these locations complained about a complete loss of KNOW's analog modulation. The locations fell roughly in the nulls of KNOW's 10-bay analog antenna. MPR's documentation provides us with the opportunity to calculate the average D/U level which results in interference and to extrapolate the results to other combinations of antenna bays and radiation centers. By the way, after logging the initial listener complaints, MPR engineers shut down the 1-bay IBOC antenna system and replaced it with a high-level combined system, thereby solving all the complaints at once.



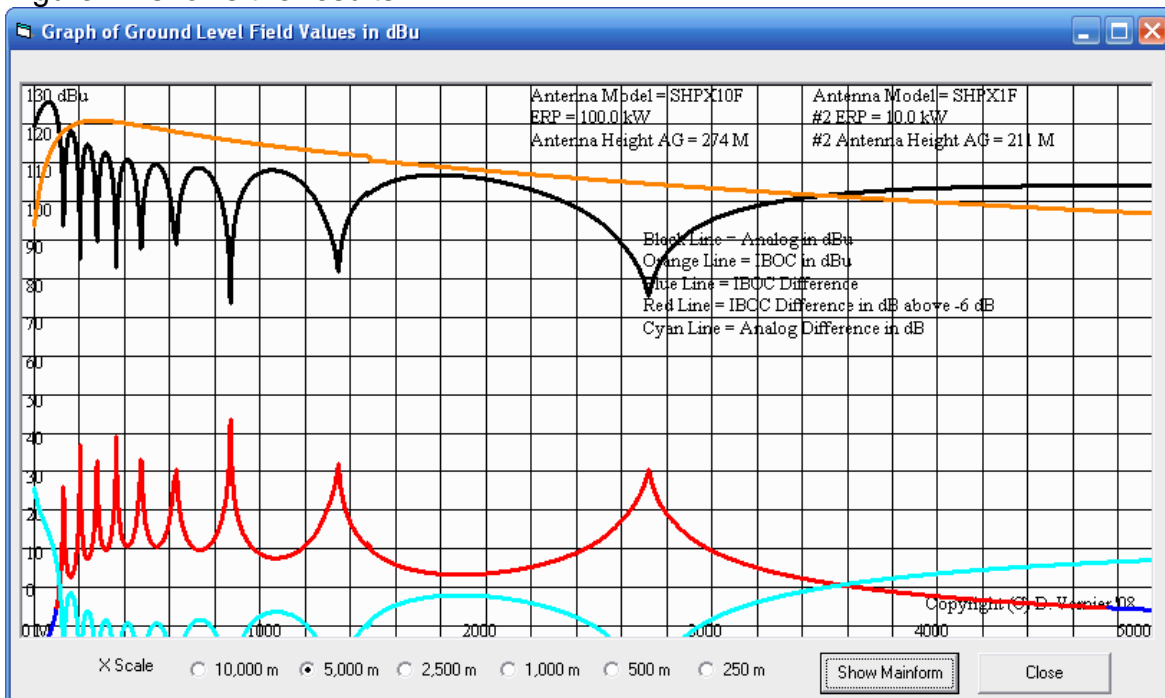
To look at why this interference was being caused at these locations, a computer program was built to plot and compare the KNOW analog and digital signal strength in dBu from the tower base out to 5000 meters (3.1 miles.) This program loads the vertical elevation field files for the 10-bay analog and the one-bay IBOC antenna and uses basic trigonometry to determine the distance and angle from the antennas on the tower to various locations on the ground. With this information we can determine the radiated power at the calculated angle ($ERP \{at\ angle\} = \text{Vertical Elevation Field} \{at\ angle\}^2 \times \text{the antenna's maximum ERP}$) and then by using the FCC curves we can determine actual signal strengths at the listener's position. Figure #3 shows the point locations along a horizontal scale of distance and a vertical scale of signal in dBu. The analog signal is plotted in black, while the digital signal is in orange. At the bottom of the graph is a difference plot. This plot turns red when the 1st adjacent IBOC signal strength is six dB or less below the signal strength of the analog carrier. The six dB value was chosen because the FCC has established a desired to undesired protection ratio of at least 6 dB for 1st adjacent station relationships. This value works very well for our predictions, because the interference complaint locations fall nicely on or near the red line peaks where the IBOC exceeds the analog signal by -6 dB or greater. The lighter blue line is the difference in dB between the analog carrier and the digital

carrier. No attempts were made to reconcile the difference in geographic coordinates because both antennas were mounted on the same structure.



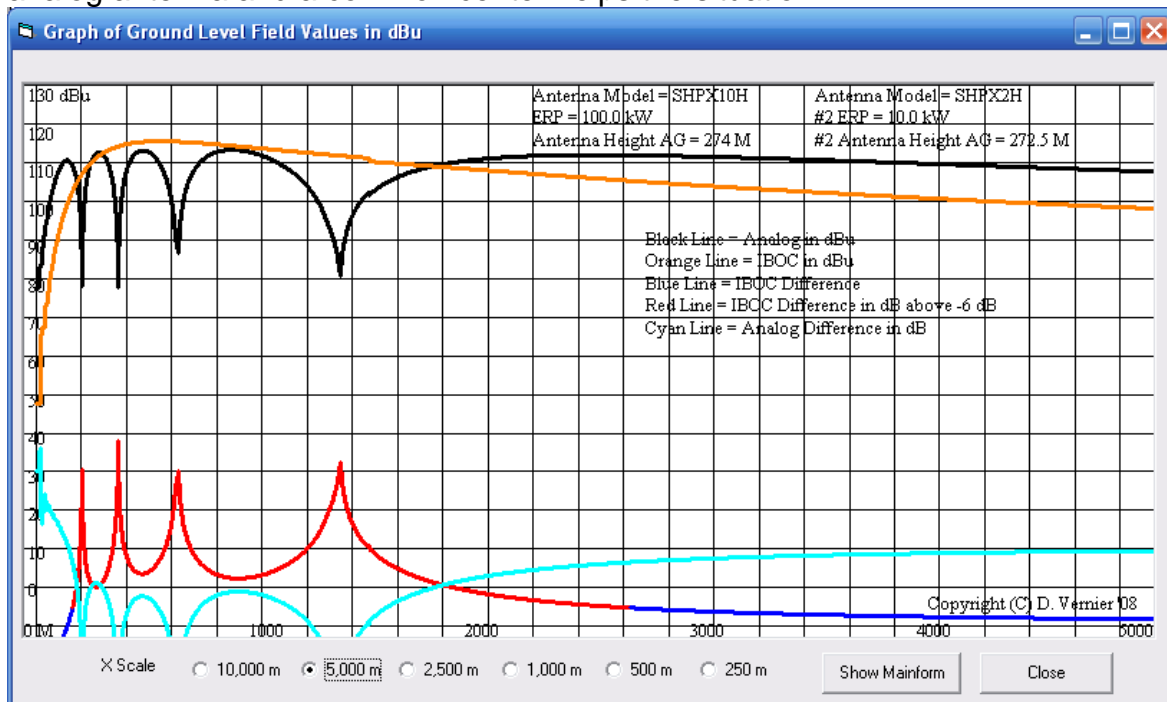
While the 11 listener complaint sampling is small and certain radios are better than others at rejecting first adjacent interference, there is, nevertheless, good agreement between the alignment of the interference complaints and the peaks of the red IBOC difference signal. With this information in hand and by using the computer program we were able to predict the location of the host interference with other configurations.

The Figure #3 graph was made when KNOW was transmitting IBOC at -20 dBc. To determine what the interference would look at -10 dBc, we ran the program with 10 kW versus 100 kW. The antenna heights above ground remained the same at 211 meters for the IBOC antenna and 274 meters for the analog antenna. Figure #4 shows the results.

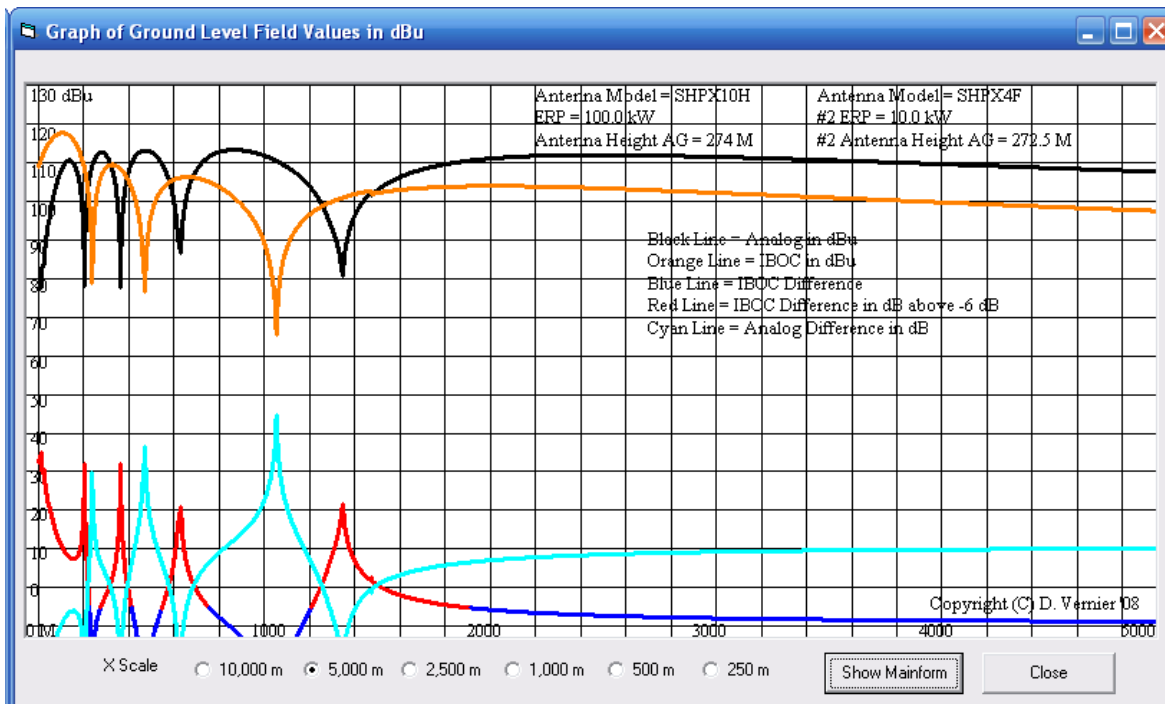


Notice that the red IBOC difference graph line shows interference to the host from the IBOC sidebands from 60 meters to 5000 meters from the tower base. At some points, the IBOC carrier exceeds the analog carrier by more than 30 dB with one point exceeding 40 dB. This would clearly be a bad situation for any station having a transmitter in an urban area.

What about moving the antenna centers close together by interleaving a two bay IBOC antenna with the 10-bay analog, will that help? The graph in Figure #5 shows what this would look like at a -10 dBc IBOC power level. Not a pretty picture, but the interference area is reduced by nearly one-half as it travels out to approximately 2600 meters. Clearly, having more IBOC bays to match the 10-bay analog antenna and a common center helps the situation.

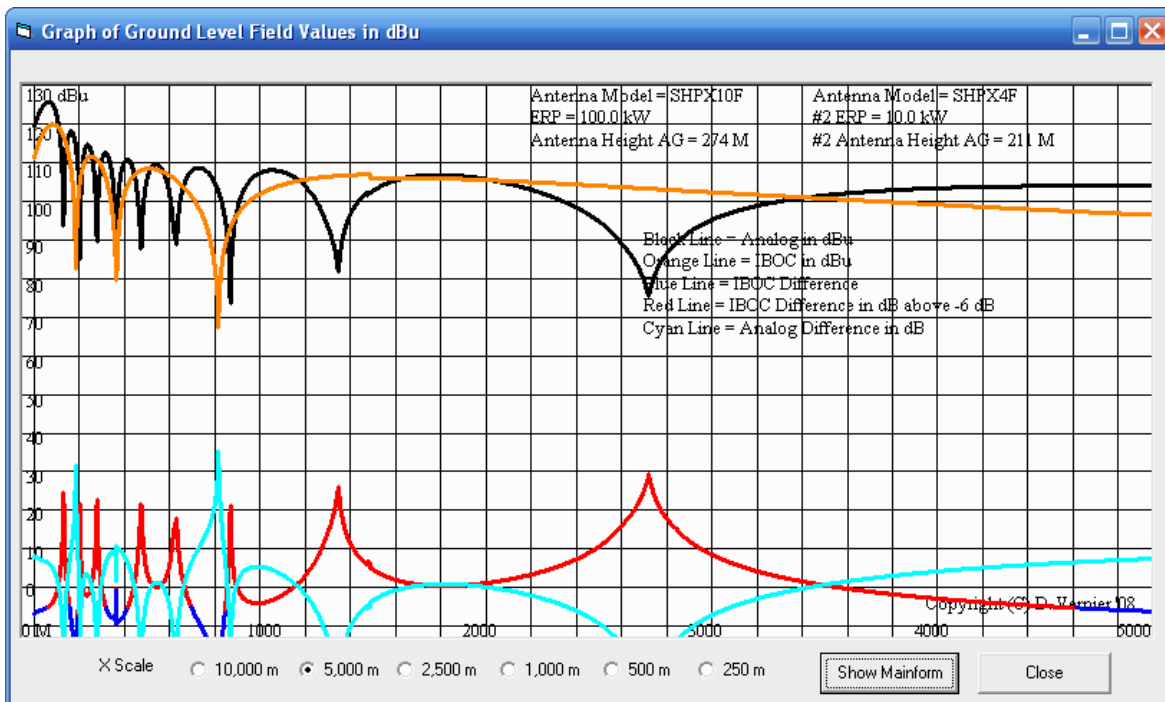


However, it appears that even an interleaved antenna will cause substantial host interference when only two IBOC bays are used. Figure #6 shows the results if we double the number of bays to four with an interleaved antenna at -10 dBc IBOC injection.

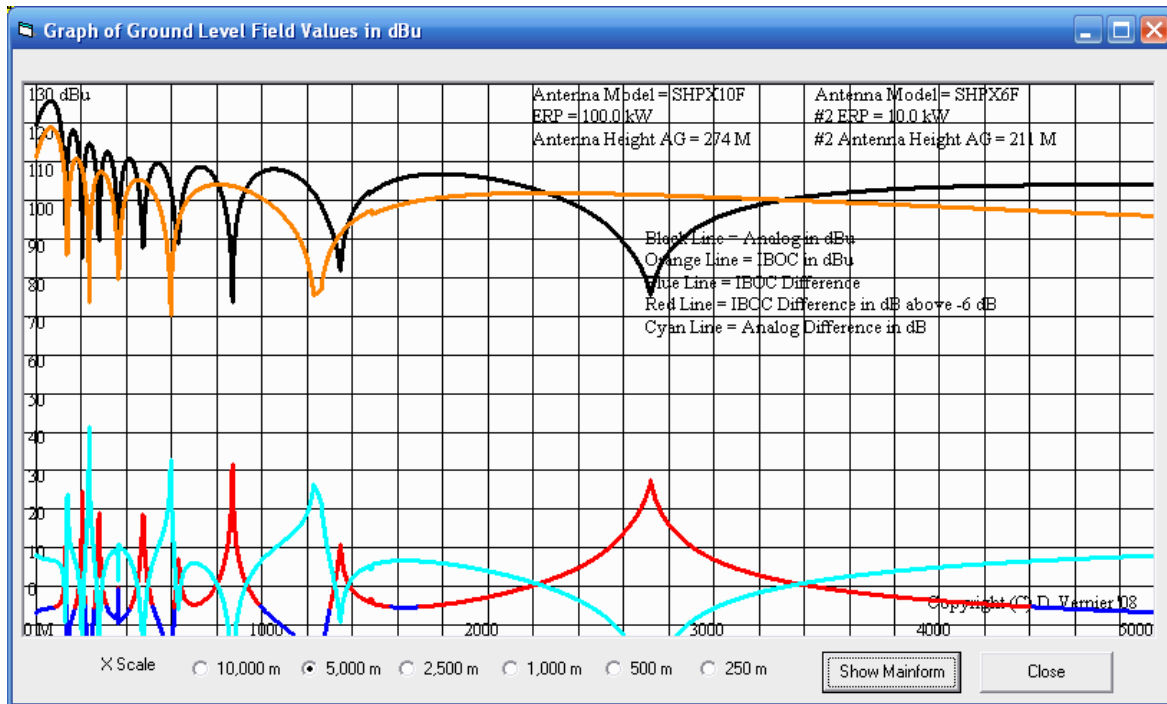


The interference area is from the tower base to approximately 1950 meters, a small improvement. Some interference has been removed in several places including from 590 meters to 1100 meters from the tower base. .

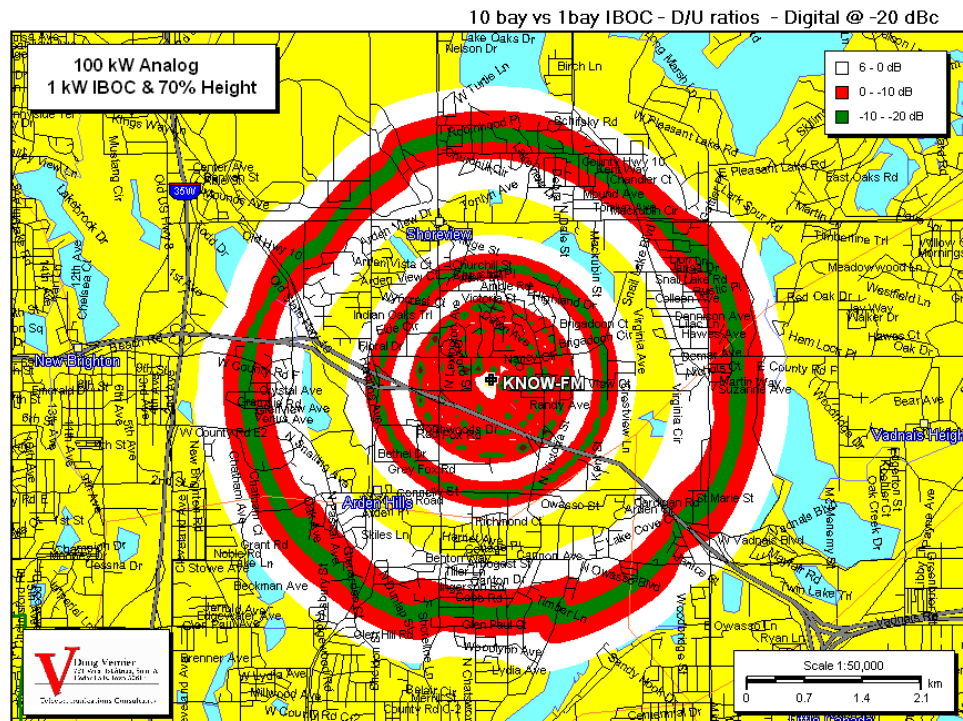
For comparison purposes of the dual 10-bay analog and the 4-bay IBOC (non-interleaved) antennas, let us return to the use of a 10-bay at 274 meters and a 4-bay antenna at 211 meters above ground. (Figure #7) As you would expect, this arrangement does not look very good.



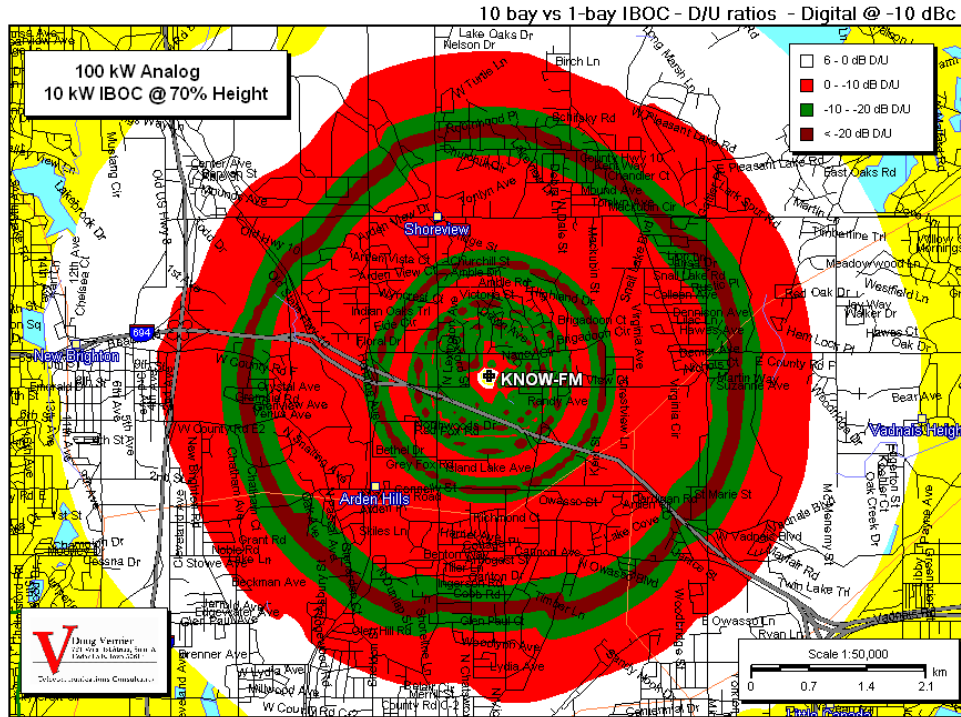
What about adding more bays to the IBOC antenna? In Figure #8 we look at a six bay IBOC dual antenna and a 10-bay host antenna.



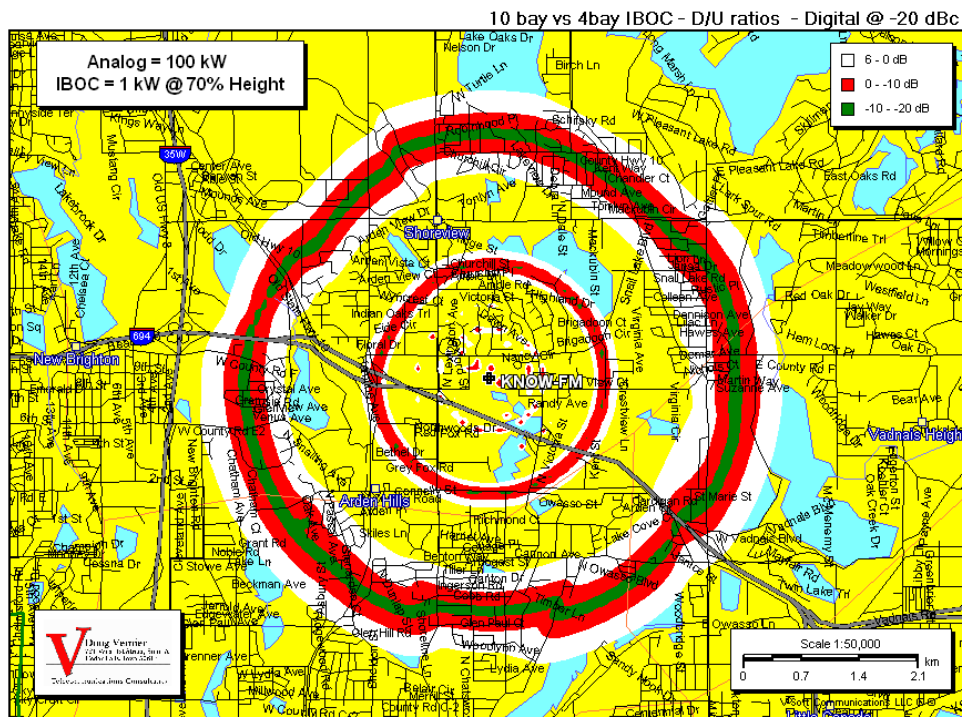
This arrangement also looks pretty bad. We can predict IBOC interference in another way. The map in Figure #9 was created using the V-Soft Communications' Probe 3 software. The FCC signal prediction method was selected. The KNOW 10-bay analog vertical elevation field pattern was loaded with the IBOC one-bay antenna. The antenna was located vertically on the tower using the original KNOW heights which was within the FCC's 70%. We told the program to create color bands representing an analog to IBOC D/U ratio which was to be 6 dB or less. As you can see from the Figure #9 map, the interference bands at the -20 dBc power level are significantly large.



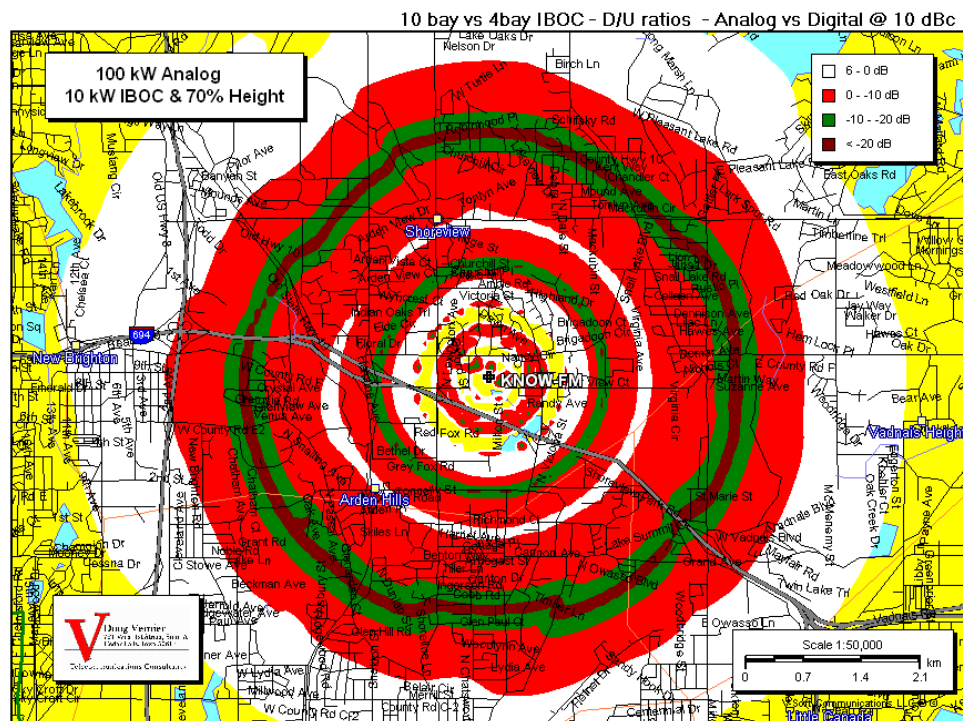
The map in figure #10 shows the interference area under -10 dBc operation and it uses the same scale as the -20 dBc map in Figure #8.



Clearly, the host interference at an elevated power level of -10 dBc is unacceptable. The map in Figure #11 plots the interference area with a 10-bay analog and a 4-bay digital antenna. The antenna heights are the same, offset by 63 meters, but the IBOC power is reduced to -20 dBc.



The map in Figure #12 shows the 10-bay antenna with a 4-bay IBOC antenna at the KNOW original height with an IBOC power level of -10 dBc.

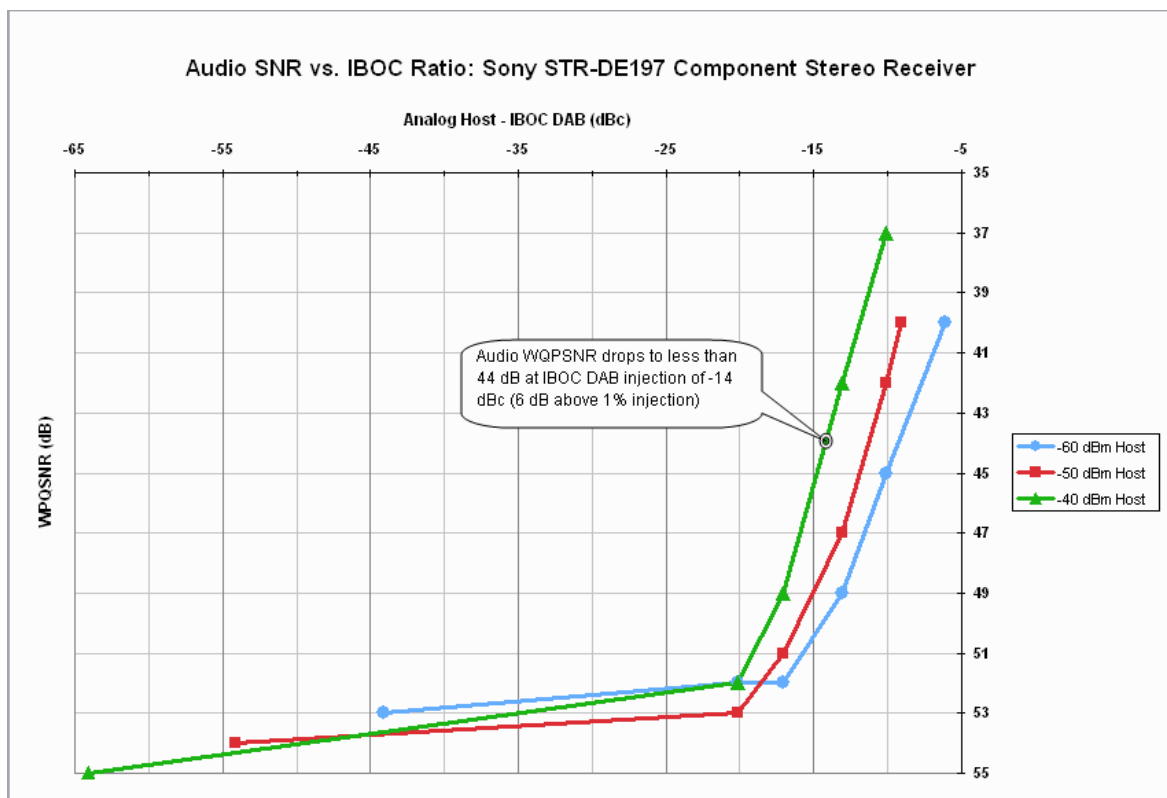


Any time an antenna is side-mounted on a tower, the tower itself causes a distortion of the pattern. Generally, the vertical steel elements can absorb the vertically radiated signal going through the tower but reflect it in the opposite direction. The same can occur for the horizontal polarization but to a lesser extent. This is why engineers almost uniformly mount an antenna on the side of the tower favoring the community of service. So, if dual antennas are used, they should both be mounted in an identical manner and occupy the same side of the tower. Another problem can occur when the IBOC antenna is mounted at a point where the tower face size differs from the analog mounting location such as in a tapered tower.

In this article, we have not examined the impact of dual antennas having a different horizontal center. While the FCC allows a difference of up to 3 seconds, (about 300 feet) if the antennas are installed in this manner it changes the angle to and the ground location of the nulls in respect to the analog antenna. This is a further departure from an identical mounting and a common center for the antennas which, as we have observed, helps to prevent interference to the hosting station. This type of an installation for an IBOC transmitter is perhaps the least attractive of all.

As already mentioned, the results of these studies are tempered by the specific interference rejection characteristics of each receiver. There have been few studies of analog receivers to determine exactly how they perform when the host station transmits IBOC. To gain more information about this effect, NPR Labs recently studied the Sony DTR-DE197 component receiver. This receiver should be somewhat representative of the higher-end component receivers available on the market. The graph in Figure #13 shows the results of their study. This graph plots the weighted quasi-peak signal to noise ratio (WQPSNR) against the IBOC power level. Three receiver signal strengths were plotted as is represented by the green, red and blue lines. At an IBOC power level of -20 dBc, with a signal strength of -40 dBm at the receiver terminals, a combination which best represents close-in host IBOC relationships, the WQPSNR for this receiver is 52 dB. In its *Digital Radio Coverage and Interference* study (NPR Labs used 40 dB WQPSNR as the point where subject listeners reported that “good” reception was lost.) The graph shows that at -10 dBc the WQPSNR drops to 45 dB. However, at the weaker signal levels of -50 dBm and -60 dBm the signal to noise ratio drops to 42 dB and 37 dB respectively.

These results indicate that increasing the IBOC power level inevitably puts more noise in an analog receiver. While the receiver studied is only one of many, it should be somewhat representative other higher end receivers in its class. Such receivers are usually better able to reject the interference which is more common in lower end radios. NPR Labs, senior engineering technologist, John Kean, reports that NPR plans to study many more receivers in the future.



By using existing data from the KNOW experience, we can predict the location of host interference. Dual antennas with differing centers and numbers of bays will not avoid this interference. At -10 dBc the host interference can be widespread. Interleaved antennas perform better, yet interference cannot be completely avoided without using the same number of bays. Stations in urban areas need to be critically aware of the looming dangers in the path to elevated IBOC power.