Antenna Location is not an Architectural Decision

By Alfred T. Yerger II, RF Engineering Specialist
Bird Technologies

Antenna system design and placement is critical to proper system performance.

Here at Bird Technologies we assist many land mobile radio customers with interference problems through our Site Optimization Services (SOS) department. Over the years it feels like we must have encountered almost every type of antenna system and interference problem (that's not actually true, we often encounter a "new one"). There is however, a recurring theme in many of the problems we encounter, and that is antenna placement. Whether the issue is intermodulation, receiver desensitization, transmitter noise or adjacent channel interference, the real source of the problem is often antenna location. Yes, many problems can be resolved through proper filtering but some can't and when this occurs, there is often a high price to pay, not only in dollars, but also in system performance and landlord relations.

Most systems today are quite complex involving many frequencies and sites. It is usually necessary to identify potential antenna sites early in the process so that system coverage and the number of sites can be determined so the remainder of the hardware design can be completed. At this point, project managers and other site acquisition people fan out to locate and lock in the necessary antenna sites. This is where the problem begins. In order to obtain the necessary site leases, landlords often want specific antenna locations or insist or identifying the locations themselves. These decisions are often made based on minimal or no system engineering information and are sometimes simply based on aesthetic concerns. What location looks the best, or "I don't want to be able to see the antennas from the street". When antenna placement decisions are made in this manner, without proper engineering input and review and then locked in through the site lease, there is often trouble ahead.

Antenna Placement Considerations:

If I had to choose only one specific parameter for antenna placement it would be separation. Physical and electrical separation of antennas is your best ally for the prevention of interference. Often, when we investigate an interference problem, particularly intermodulation, one of our first questions is, can we get more antenna separation?

As antennas are separated the amount of signal coupled from one antenna to another is significantly reduced. Horizontal separation, such as on rooftop sites, tends to follow the free space law that says the signal level will drop by 6 dB (75%) every time you double the distance. If we are fighting a third order intermodulation problem, the resulting IM product will drop 3 times the reduction in fundamental signal level. In our example, if we double the distance between the antennas, the signal levels will drop by 6 dB and any intermodulation products produced by those fundamental signals will drop up to 18 dB.

Antennas closely clustered on top of elevator penthouse.

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Vertical antenna separation is even better. Significantly more isolation can be obtained by separating the antennas vertically. Based on industry standard isolation charts, spacing two VHF antennas 10 feet apart vertically will provide approximately 35 dB of isolation while 10 feet of horizontal spacing will provide less than 20 dB of isolation. These numbers are the subject of some amount of debate. One of the issues is whether or not to include antenna gain. It has been our experience that antenna gain reduces the isolation between antennas horizontally separated and increases the isolation of vertically spaced antennas. One more caveat, to obtain maximum vertical isolation, the antennas must be located exactly above and below each other. Any offset will reduce the isolation. Also remember that none of this is precise. Transmitted energy coupled into other structures such as the tower or the rooftop antenna grid can be conducted along the structure and coupled into other antenna(s), thereby reducing the isolation.

Antenna Placement Guidelines:

Optimum design of the antenna system can only be achieved if all of the RF parameters are known. Realizing that this is seldom the case we can still make some choices that will minimize the probability of serious problems.

As much as possible we want to maximize the isolation between transmitting and receiving antennas. On towers this usually means the best possible vertical separation. In addition, when possible, group receive antennas together on one level and put transmit antennas on another level. Also, conventional wisdom has always told us to put the receive antennas at the top of the tower but things have changed and conventional wisdom doesn’t always apply. First, most public safety systems use voting receiver systems with a good deal of overlap so it is no longer necessary to squeeze every dB out of the receive system. Second, we have discovered that if the transmit antennas are above the top of the tower, there is less illumination of the structure, less passive intermodulation (PIM) and less coupling through the tower allowing us to achieve maximum isolation.

Now if you have multiple levels of transmit antennas then putting the receive antennas at the top my still be the best choice. In any case they should be isolated from transmit antennas within the same band and from all transmit antennas whenever possible.

On building tops you are usually limited to horizontal separation. In this case all you can do is try to achieve the best isolation possible. Again, separate the transmit and receive antennas as much as you can. If the building will allow you to construct a tower on the roof, this is an excellent choice as you now have the option of achieving some vertical isolation.

If you know the frequency plan you are in much better shape. Do an intermodulation prediction study on the frequencies. Be sure to include any other frequencies you know to be at the site. To determine who else is at the site we routinely utilize a computer controlled spectrum analyzer to study the spectrum and determine what, if any, high level carriers exist at the site that should be included in the IM study. If the program predicts any IM “hits” you can take this into account in your antenna system design.

As a general rule of thumb, try to eliminate any 3rd order products if possible. This will usually require at least one transmitter to change frequency. If you have IM products that you cannot eliminate through frequency changes then all you can do is try to maximize the isolation.

Most systems utilize some amount of transmitter combining. Do not put transmitters that produce IM products into the same combiner. This is especially true of 3rd order products. Any predicted 3rd order products in the same combiner will occur and will drive you crazy.

The isolation required to eliminate or minimize intermodulation represents a 3 way puzzle for the site designer. We want to achieve maximum isolation between the antennas radiating the signals that could potentially mix and we also want to achieve maximum isolation between the transmit antennas and the receive antenna feeding the potential victim receiver. On a tower this will normally require three antenna mounting levels. It would be best if the three antennas were directly above each other but at a minimum they need to be on different levels with as much separation as is practical.

On a building top, we need to try to achieve the largest possible triangle with the three antennas to achieve maximum isolation.

470 MHz and 800 MHz antennas in close

Some combinations of frequencies seem to be worse than others. One classic example is when 470 MHz and 800 MHz stations share the same rooftop. When 800 MHz licenses were first issues the frequencies were issued in groups of 5 with 1 MHz between the channels. Many 800 MHz systems still have channels spaced 1 MHz apart. In a group of 5 channels with 1 MHz spacing there are 2 combinations of frequencies that have 3 MHz spacing between then, channels 1 and 4 along with 2 and 5. 470 MHz repeaters have a 3 MHz spacing between transmit and receive. When these two conditions are brought together in close proximity a very problematic 3rd order IM product develops that falls on the 470 MHz repeater receiver resulting in a feedback loop between within the UHF transmitter. Even with all the transmitters and receivers properly filtered and the transmitters outfitted with isolators, the IM is likely to occur as it can still be produced externally as passive intermodulation (PIM). The only solution is to obtain sufficient antenna isolation. If the antennas are clustered together, the probability of producing the IM is nearly 100 %.

As you can imagine, much of this does not fit well with a landlord's or building owner's idea of where the antennas should be placed, or a tower owner's desire to fill a particular space on the tower. However, failure to follow through with proper site design could potentially leave you with problems that can only be solved by either relocating the antennas or someone vacating the site. We have seen customer's with their backs hard against the wall, when problems have occurred and there seems to be no avenue to a resolution. It would be much easier to either bring engineering in earlier in the process or try to negotiate some flexibility into the site lease with regard to antenna placement.

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Disclaimer: The pictures in this article are to illustrate antenna mounting configurations. No statement is being made regarding any problems that may exist in these specific installations.