



Antenna Location Is Not An Architectural Decision

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

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

Here at Bird Technologies Group, 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 known to man. (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 of today's systems 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 and 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 on identifying the locations themselves. These decisions are often made with minimal or no system engineering information and are sometimes based on purely 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 (IM) problem, the resulting IM product will drop three 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 can decrease as much as 18 dB.



Antennas closely clustered on top of elevator penthouse

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 debate, however. One of the issues is whether or not to include antenna gain. It has been our experience that antenna gain reduces the isolation between horizontally separated antennas 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 then radiated 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 the 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.

If you have multiple levels of transmit antennas, then putting the receive antennas at the top may still be the best choice. In any case, they should be isolated from transmit antennas within the same band and from all other 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 will be present 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 third-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.

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

The isolation required to eliminate or minimize intermodulation represents a three-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 connected to 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.

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 issued, the frequencies were issued in groups of five with a 1 MHz spacing between the channels. Many 800 MHz systems still have channels spaced 1 MHz apart. In a group of five channels with 1 MHz spacing, there are two combinations of frequencies that have 3 MHz spacing between them: channels 1 and 4, and channels 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 third-order IM product develops that falls on the 470 MHz repeater receiver, resulting in a feedback loop 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 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%.



470 MHz and 800 MHz antennas in close proximity

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 customers with their backs 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.

Remember, antenna location is not an architectural decision!

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

About The Author

Alfred T. Yerger II is an RF engineering specialist for Bird Technologies Group, specializing in field engineering for the land mobile industry including antenna site design, noise and interference, and communications system coverage issues.

Mr. Yerger has been working in the radio communications and broadcast industries since 1974, including 18 years with Motorola Communications. He joined Bird Technologies Group in January 2005, after running his own business, Antenna Site Technology Inc., for 6 years. He is the senior engineer in Bird's Site Optimization Services (SOS) department. In this position, Mr. Yerger is responsible for supporting Bird's spectrum monitoring and noise measurement services, interference mitigation, and training for the land mobile communications industry.