Finding, Solving, and Preventing Intermodulation Problems by Softwright

Symptoms of Intermodulation Products

Simply put, actually too simply put, intermodulation (IM) products are interference. They are undesired interference to a desired signal from a destructive combination of transmitted signals typically where a desired signal must be received. IM products are almost always intermittent because the transmitted signals, which combine to produce the IM, are not transmitting continuously. When the amplitude of the IM product is sufficiently large, it can degrade or overtake the desired received signal by the receiving equipment. This type of interference can render the desired radio link to be completely unreliable. Although intermittent, intermodulation products are usually repeatable so long as all the component frequencies needed to generate IM are simultaneously present at the same point in time.

There are many types of interference. Certainly not all interference is caused by intermodulation. Some such examples are co-channel (someone else, generally some distance away, using the same frequency as you) and adjacent channel interference (signals on a frequency different from but close to your desired received frequency). Other examples include manmade noise from induction devices such as motors and internal combustion engines as well as spurious emissions from non-radio devices such as computers, medical devices and welding equipment. Certain atmospheric conditions such as high moisture content or lightning can also cause significant interference to radio systems in certain frequency bands. None of these types of interference result from the generation of intermodulation products. These interference problems must be treated quite differently from intermodulation interference.

In order to eliminate any particular type of rf interference, you must first identify with great certainty both the type and source of the interference. Adequate research into interference types and sources will pay off economically, when it is time to perfect the cure. Also, be aware that not all types of interference are curable. Sometimes the solution is for one or more frequencies to be changed to one that will no longer cause the interference. While some techniques and solutions used to resolve these types of problems are some-what similar to those used to resolve intermod, the scope of this paper will be limited to the prediction, diagnosis, resolution and prevention of destructive intermodulation products.

Intermodulation products are the emissions at frequencies generated by the combination of two or more frequencies in a non-linear device, such as the output stage of a transmitter, or the input stage of a receiver. A non-linear device is one whose output signal is not directly proportional to its input signal. A simple example of such a device is a diode. The output is clearly a function of the input signal but not proportional to it. The output signal is typically very distorted and an increase in the input level will not produce a directly proportional increase in the output signal level. This is precisely the definition of a non-linear device. This type of device provides a great source of irregular combinations of signals, often not as we might desire them to be combined. Transistors and certain integrated circuits are also a common source of intermod products generation. While these non-linear devices are normally biased into a near-linear region for normal operation, a high level of received signals (including intermod) can overdrive these devices into a non-linear region. This will almost certainly generate intermod.

Whenever two or more signals are present in a non-linear device, the possibility exists that an intermodulation product will be spontaneously generated as some combination of sums and/or difference between the frequencies involved. The contributing frequencies can be fundamental carrier frequencies radiated from transmitters operating in the nearby vicinity. They can also be harmonic products of those carriers (twice the frequency, three times, etc.) which may also be radiated if the proper suppression equipment is not installed or properly tuned at the transmitter output.

There are a number of commonly observed problems that often indicate the presence of intermodulation products. Some-times the receiver might not open the squelch when it should. You are not able to bring up the repeater from a portable unit located in an area that should be able to easily work the repeater. The repeater might be coming up "randomly", when no one is deliberately keying it. You might have highly distorted audio through the repeater. In the audio you might be hearing more than one user at a time. Your audio might also be present in someone else's system. Another problem that can occur is hearing music on your two-way if the repeater is located near a FM broadcast station. Intermod distortion sometimes sounds like birdies, hum and even chirps. These problems will usually be intermittent. In a digital system a common consequence of intermod is a destructive increase in the bit error rate (BER). This then will degrade the throughput of the link, rendering the data telemetry or voice communications unusable.

Types and Sources of Intermodulation Interference

Actual generated intermodulation products will usually fall into one of the following categories:

Transmitter generated intermod

The transmitted signal from one or more transmitters is received at the output of another transmitter generally via this transmitter's antenna. This received signal must be of sufficient strength to mix with the transmitter's own carrier in the non-linear final amplifier. This newly mixed signal is then amplified and transmitted along with the desired carrier. This is the most common type of intermod and also the easiest to cure.

Receiver generated intermod

Transmitted RF energy can sometimes generate a voltage in a nearby receiver's RF amplifier, biasing a transistor into a non-linear state that allows it to act as a mixer (a device that will combine different frequencies and produce rf signals on frequencies other than those that are supplied to it), which in turn become the unwanted IM products. This undesired signals can be received via the antenna input or can sometimes be coupled directly into the receiver through the case. This process is a common source for generation of IM products. Receivers can also be desensitized by intermod. When that happens a strong intermodulation product actually received in the front end can overdrive the receiver, causing the automatic gain control to reduce the gain even if the intermod is on a frequency other than the desired received frequency. This will then also reduce the received level of your desired frequency, often to the point where it cannot be detected by the intended receiver, again rendering the link unusable.

Externally generated intermod

Loose mechanical connections or dissimilar or corroded metal connections form non-linear electrical junctions, which act as unintended "diodes" or mixers. When these devices are excited by sufficient level of one or more signals they generate IM products. Major offenders are tower section joints (especially if they are heavily corroded), broken welding beads, improperly seated or corroded connectors in the RF chain, metal buildings, and chain-link or barbed-wire fences. These are by far the most difficult sources to identify. Once they are identified, many conventional solutions exist that will usually eliminate the problems of interference that they cause.

Definitions of Terms

Intermodulation product -A measurable signal at a specific frequency (or occasionally multiple signals over a specific bandwidth) generated from a combination of radiated signals, which are received at a site and which can cause interference to some desired received or protected frequency.

Protected frequency -A frequency, generally a received frequency at a site, that you wish to protect from interference (can also be an IF or subcarrier frequency added to or subtracted from the carrier frequency). It can also be the center frequency of a band that you wish to protect for any number of reasons, for operation of devices such as radio-telescopes, medical instrumentation, or very high-gain amplifiers that must maintain a very low level of a noise floor in order to accomplish their desired tasks.
RX Offset -1/ 2 the bandwidth of the frequency spectrum you wish guarded around the protected (received) frequency when you do an intermod study. This offset frequency is the amount both below and above the protected frequency that will be checked by the intermod software to determine if any predicted products might be generated.

TX frequency -Fundamental carrier frequencies transmitted at the site that you wish to include as possible offending signal sources.

TX Offset - The maximum frequency away from the transmitted carrier, which can contain modulated information.

Number of harmonics -You must specify from one through nine harmonics of the particular transmitted frequency, that you wish to be considered as possible participating components for an intermod hit in any study, even though these devices usually have bandpass filters on them. Should these filters not be properly tuned, they would not provide the side-band rejection that they should. These signals can cause problems. If a particular transmitter is high powered, such as TV or FM broadcast, you should consider a higher number of harmonics than if the transmitter power is relatively low. It is typical to consider up to the 7th harmonic for television with an effective radiated power of several MW and the 3rd harmonic for a two-way repeater with a few hundred watts of effective radiated power (ERP).
Facility description -Designated call sign or user ID that will help you associate the actual users with the list of frequencies you use in your intermodulation study.

Number of components -The number of transmitted frequencies that are used to generate the intermodulation product or hit. This is typically two or three frequencies. IM products resulting from four or more frequencies, while mathematically possible, are extreme cases, unlikely to be encountered in real world situations. Checking intermod combinations of more than three frequencies at a time will significantly increase the execution time of the intermod program.

Order of product -The sum of the absolute value of coefficients of all components of predicted intermodulation product. For example, if the intermod product generated is at 385 MHz and results from the combination of the second harmonic of 155 MHz adding with the fundamental of 75 MHz, the prediction would show as 2x(155) + 1x(75) = 385 MHz. The order of this particular product would be the sum of 2+1 or 3rd order product. The most likely hits to be generated are the lower order products, generally at or below 5thorder. Checking for intermod higher than 5th order will also significantly increase the execution time of the intermod program.

Simplex operation -Transmitting and receiving on the same frequency (non-concurrently). The TAP software is configured with the default to ignore hits that are calculated if one of the offending participating frequencies is the same as the same frequency (simplex). This can be turned off on a frequency by frequency basis, should the user wish to do so when the study is done.

Half-duplex operation -Transmitting and receiving on different frequencies not simultaneously (not tested in IM program because it cannot cause a problem).

Full duplex -Transmitting on one frequency while simultaneously receiving on a different frequency. Testing for this is automatically covered in the software.

Use Predictive Tools for Intermod

Intermod products predictive software, such as the Intermod Module of the Terrain Analysis Package (TAP), can be used to bring to your attention the possibility of IM problems both prior to actual construction as a preventative tool as well as a diagnostic tool after construction is completed and a problem is suspected. When you are proposing the use of a new transmit and/or receive frequency at a site, it is wise to run an intermod study using the precise frequencies actually transmitted and received. This provides a basis for evaluation of the combining potential with a newly proposed frequency before it is in actual operation. This can bring both great assurance as well as due caution before a new facility is actually placed in service. Using the studies as a diagnostic tool when IM problems are known to exist is equally valuable. This will help you identify and solve a critical problem after its actual presence has been confirmed by the degradation or elimination of long established radio service.

A database of all transmitted and protected frequencies is prepared. Whether this is an existing site or a newly proposed unconstructed site, you will need to acquire an exhaustive list of all frequencies used at the site as well as other nearby locations. As you enter the information into the database you will need to make several assessments about the information. For each frequency you will have the option to include an assigned call sign or user name. Doing this will facilitate your interpretation of the output results by allowing you to associate which user is potentially affecting which other users. Along with each transmitting frequency you will need to make a decision as to up to what harmonic level you wish the software to consider each transmitted frequency.

This decision will be based on your assessment of the likelihood of energy being radiated at those frequencies. For example, a relatively low power level transmitter (up to a few hundred watts) is not likely to radiate much energy above the third harmonic. If such was the case, it is likely that other performance characteristics would be so degraded that repairs would be in order. If, on the other hand, normal transmitted power is many thousands of watts, it is possible that you might wish to consider the possibility of including up to the 5th or 7th harmonic as possible participating frequencies. The TAP intermod software will let you consider up to the 9th harmonic in these studies as a possible offending participating frequency.

Along with each protected frequency you will need to specify a guard band around each one. This is the band of frequencies that if interfered with would cause your desired received frequency to be unreliable. This can be set differently for each protected frequency. The bandwidth of this protection guard band will generally be dependent upon the width of the assigned channel or the actual spectrum used by the particular type of modulation employed. It can also be determined by the selectivity of your receiver. The actual program input you will enter will be the offset in kHz that you wish protected both above and below the specified protected frequency. Any calculated hits that fall within this offset from your protected frequency (both below and above) will be included in the results database and listed as output from the program.

You will need to input the maximum number of participating frequencies (components) that you wish considered in the study. It is very rare to see more than three components actually combine to produce an IM product. The software will allow you to consider up to a maximum of four simultaneous components.

The output from the intermod software is used to calculate the results of an intermodulation products study by evaluating the included proposed and/or existing facilities at the site. It considers the transmitted frequencies through the specified level of harmonics, taking into account all possible combinations of the proposed facilities. In addition to the fundamental transmitted frequencies, one or more other transmitting frequencies and their specified harmonics are also considered as possible components. The possible intermodulation products are then compared to all received or otherwise protected frequencies used at the site to determine possible areas requiring attention. All visual and aural received carrier frequencies, as well as chrominance sub-carrier frequencies for television translators in use, should be included in the input database. A generated hit frequency, which falls not exactly on, but close to a protected frequency, can also create problems. Therefore, any combination that results in a possible hit within the specified guard band (from the offset below to the offset above the protected frequency) will be listed as a possible intermod product in the results database.

The report generator then reads the results database and allows you to filter this information into meaningful reports. You can have multiple levels of filters on the results database. The variety of sorts and filters allow you to manipulate the results to find information about specific suspect transmitters or specific problematic receivers. For example, you can sort the data by the order of hits or by the frequency of the generated intermodulation product. You can also filter the results by including only certain ranges of hit frequencies or number of participating components. You can see only the possible hits with which a particular transmitted frequency is a participant. You can filter the results on almost any parameter used in creating the study.
These reports can be printed out and saved as ASCII files, which can then be imported into conventional word processing software for presentation of your analysis of the results of the study.

In evaluating the likelihood of possible interference resulting from the mathematical combinations computed, several factors are pertinent. Clearly a direct hit exactly on a protected frequency is of a much greater concern than a hit that is significantly removed from the protected frequency. The higher order the product, the lower the likelihood of its being generated, because the statistical likelihood of two frequencies combining is greater than a combination of three frequencies.

Products above 5th order are very rare. The reduction of effective radiated power of the proposed fundamental frequency due to considerations of the antenna's azimuth and elevation radiation patterns also should be considered. If the effective radiated power (ERP) levels radiated from a proposed antenna in the direction of the receiving equipment is on the same order of magnitude as other existing transmitting equipment, it should not cause radically higher levels of desense or interference from intermodulation products. When there are largely different levels for ERP, the substantially higher-powered level carrier is of much greater concern. However, with proper isolation this can almost always be satisfactorily dealt with in the site design. Intermodulation products generated in existing receivers resulting from the fundamental carrier frequency can be substantially reduced or eliminated through the use of notch filters, as discussed below. If the power levels anticipated are on the same order of magnitude as other signals present, the selective attenuation achieved by the use of filters will often provide adequate protection.

Those possible intermodulation products resulting from the combinations of second and higher order harmonics from the proposed and/or existing equipment are of lower probability because of the stringent FCC regulations regarding spurious radiation and the suppression of harmonic frequencies. Television translators operating at powers greater than 100 watts must suppress harmonic radiation by at least 60 dB (see Section 74.736 of the FCC rules). Land mobile radio equipment (Section 90.209) must suppress harmonic radiation removed by 2.5 times their specified bandwidth by 80 dB or the computed value of 43 dB+ 10 log (output power in watts), whichever is less. The same requirement is imposed on FM broadcast facilities for frequencies greater than 600 kHz from the fundamental frequency. Thus, the signal levels of harmonic radiation from properly adjusted and operating equipment are attenuated to levels far below normal operating signal levels, and provide minimal contribution to generate intermodulation products. However, improperly tuned harmonic traps on a transmitter can increase the likelihood of intermod. Many times the proper tuning of these filters and thereby bringing these transmitting facilities into compliance with Federal Communications Commission requirements can easily eliminate it.

It should be remembered that while the problems under consideration are mathematically possible, a certainty of interference is not implied. The purpose of a study and discussion of this type is to predict and anticipate the more likely potential problems. Experience has clearly demonstrated that the successfully operation of congested two-way radio, cellular and broadcast radio/television transmission/receiving sites is very common, even when predicted interference studies indicate the possibility of problems. These types of multi-user sites routinely involve both high-powered broadcast facilities and relatively low powered two-way radio communications. With careful design almost every type of intermodulation product problem can be avoided and/or eliminated.

This type of electromagnetic compatibility study is particularly essential prior to construction at a multi-user installation.

Without adequate advance study unforeseen problems might surface after the installation is complete. The lack of a coherent plan for their resolution would result in great inconvenience to all offended users. Such a study as this is as important to the operators of high powered facilities, as well as lower powered equipment since the complexity of the typical FM or television signal can be disrupted by very low levels of spurious radiation, rendering sub-carriers unusable.

Case Studies of Intermod Problem Using TAP

We will now look at several case studies of predicted intermodulation products. We will examine some of these output results and analyze the level of anticipated severity of these potential products and suggest advice about possible solutions to eliminate the interference should it actually occur. The following case studies are for possible predicted IM hits. All are calculated by the Terrain Analysis Package Intermodulation Products software using 73 transmitted and 64 received frequency operated at an existing single antenna farm. The study was done employing all transmitted frequencies considering up to the 5th harmonic of each. The study also provided a guard band of protection around each protected frequency of +/- 19 kHz. To follow are very small excerpts of the results. These are actual results, but in no way should be considered an exhaustive evaluation of the results. These few specific examples were drawn from the more than 8000 specific hits calculated by the software to illustrate specific concerns. These types of results will be typical when you evaluate your program output.

Case Study #1

Any prediction of intermodulation products generated as a direct combination of fundamental frequencies should be of serious concern.
151.95500* 0.00000 MHz from 151.95500(BANK IV)
-1*(461.55000)+1*(461.02500)+1*(152.48000)

This particular hit is a predicted product that falls exactly on a specified protected frequency. Such direct hits will be noted with an asterisk (*) to the immediate right of the hit frequency – followed by a 0.00000 MHz offset from the same received frequency. This example would be of particular concern because it is produced by the fundamental frequency of all three components (indicated by the "1*( )" for each component. The treatment of this type of intermodulation product, should it occur, will require increased isolation between one or more of these transmitted fundamental frequencies and the source where the intermodulation product is actually generated. If sufficient isolation cannot be introduced, one of the three above component frequencies will probably have to be changed to a different frequency.

Case Study #2

151.95000 0.00500 MHz from 151.95500(BANK IV)
-2*(158.70000)-1*(454.05000)+2*(461.70000)
151.95000 0.00500 MHz from 151.95500(BANK IV)
-1*(931.06250)+3*(929.56250)-2*(852.83750)
151.95250 0.00250 MHz from 151.95500(BANK IV)
+1*(884.19000)+2*(929.56250)-3*(863.78750)
151.95250 0.00250 MHz from 151.95500(BANK IV)
+1*(884.19000)+2*(931.06250)-3*(864.78750)

Looking at these four hits, we learn that the receiving frequency of 151.950 MHz is particularly vulnerable to intermodulation products. Destructive IM could be generated from four different combinations of three separate frequencies. Also, all four of these possible hits can be eliminated with sufficient suppression of certain second and third harmonics of the participating components.

Case Study #3

151.95500* 0.00000 MHz from 151.95500(BANK IV)
+1*(151.95500)

An indicated hit frequency like the above would mean that the received frequency was being interfered with by the same frequency being transmitted. If the operation is simplex (transmitting and non-concurrent receiving on the same frequency) this will not be a problem. If the system is not simplex, either you have erroneously entered either the transmitting or receiving frequency or there is someone else on the site transmitting on the frequency you need to receive.

Case Study #4

456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(461.55000)+1*(453.75000)+1*(463.95000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+1*(883.14000)-1*(881.04000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(887.34000)+1*(454.05000)+1*(889.44000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(887.34000)+1*(454.05000)-2*(886.29000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+1*(883.77000)-1*(881.67000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(464.22500)-2*(463.20000)+1*(454.10000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(452.20000)+2*(454.17500)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+1*(454.05000)-1*(461.97500)+1*(464.07500)

Again in all the eight above examples, a possible direct hit is predicted. Each group of components includes one or more fundamental frequency. Isolation of these component frequencies from the source of generation is typically accomplished by notch filtering or significant vertical antenna separation.

Case Study #5

456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(885.45000)+1*(454.05000)+1*(887.55000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(884.82000)-2*(883.77000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(884.19000)-2*(883.14000)+1*(454.05000)

456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(883.56000)-2*(882.51000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(882.93000)-2*(881.88000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(888.60000)+1*(454.05000)-2*(887.55000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(882.93000)+1*(885.03000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(883.56000)+1*(885.66000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(884.19000)+1*(454.05000)+1*(886.29000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(884.82000)+1*(454.05000)+1*(886.92000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(885.45000)-2*(884.40000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(886.08000)-2*(885.03000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(886.71000)+1*(454.05000)+1*(888.81000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(886.08000)+1*(454.05000)+1*(888.18000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(887.97000)+1*(454.05000)-2*(886.92000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(886.71000)-2*(885.66000)+1*(454.05000)

The significant observation that we make from the above 16 possible direct hits is that there is one frequency that is common to each of these hits as a participating component - 454.05 MHz. Several observations are clear. If you were to relocate that operation to another frequency, all of these possible direct hits would be eliminated. Sometimes it is smart to institute this type of change, especially if the system is not yet operational. This type of precaution, if practical, can eliminate a great deal of diagnostic work should a hit actually result. If a change in frequency is not desirable, then the solution to any such hits would be filtering isolation or isolation resulting from physical antenna separation.

Case Study #6

The following 34 direct hits fall on 457.200 MHz, a frequency received by Yellow Cab.
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(885.03000)+1*(454.05000)+1*(888.18000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-2*(464.22500)+2*(461.97500)+1*(461.70000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(885.66000)+1*(454.05000)+1*(888.81000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(883.77000)+1*(454.05000)+1*(886.92000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+2*(461.55000)-3*(451.15000)+1*(887.55000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(461.55000)+2*(461.02500)-2*(463.20000)

457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(881.88000)+1*(885.03000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(884.40000)+1*(454.05000)+1*(887.55000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(883.14000)+1*(454.05000)+1*(886.29000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-2*(452.20000)+2*(453.75000)+1*(454.10000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(152.24000)+2*(152.48000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-2*(931.91250)+2*(929.66250)+1*(461.70000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+2*(454.17500)-1*(451.15000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+4*(453.75000)-1*(463.95000)-1*(893.85000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-2*(463.95000)+3*(461.70000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(454.05000)+1*(891.96000)-1*(888.81000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(454.05000)+1*(892.59000)-1*(889.44000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(463.20000)-2*(864.46250)+2*(861.46250)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(463.20000)+2*(861.78750)-2*(864.78750)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(463.20000)+2*(862.78750)-2*(865.78750)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(463.20000)-2*(865.46250)+2*(862.46250)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(454.05000)-1*(886.29000)+1*(889.44000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(888.60000)-1*(885.45000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(882.93000)+1*(886.08000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(884.82000)-1*(881.67000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(884.19000)+1*(887.34000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(888.60000)-2*(453.75000)+3*(158.70000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(884.82000)+1*(887.97000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(888.60000)+2*(461.02500)-3*(451.15000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(884.19000)-1*(881.04000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(883.56000)+1*(886.71000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)

-1*(881.25000)+1*(884.40000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(882.51000)+1*(885.66000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(885.45000)-1*(882.30000)+1*(454.05000)

From a review of the above output we see that 19 of these direct hits result from possible combination with the fundamental frequency of 454.05000 MHz. As above, it would be important to plan to provide some isolation of this frequency from the receiver operating on 457.20000 MHz. Either sufficient isolation or frequency change will directly eliminate these 19 hits possibilities. Bear in mind a change in the 454.05000 MHz transmitting frequency would eliminate these hits. A change to a different receive frequency will eliminate all of them. However, it would be very important to run an IM study to check any proposed new receiving frequency to avoid replicating a similar situation.

Case Study # 7

The following 13 direct hits were all on 458.75000.
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
+1*(461.55000)-2*(931.06250)+2*(929.66250)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
+1*(454.10000)-2*(862.46250)+2*(864.78750)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
+1*(461.35000)-1*(453.75000)+1*(451.15000)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
+1*(461.35000)-2*(461.97500)+2*(460.67500)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
+2*(931.91250)-2*(929.56250)+1*(454.05000)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
+1*(452.20000)+2*(463.95000)-2*(460.67500)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
-1*(463.20000)-1*(463.97500)+3*(461.97500)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
+1*(454.10000)-2*(863.46250)+2*(865.78750)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
+2*(461.35000)-1*(463.95000)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
+1*(454.10000)+2*(863.78750)-2*(861.46250)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
-2*(453.75000)+1*(463.95000)+2*(451.15000)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
-1*(454.10000)+1*(451.15000)+1*(461.70000)
458.75000* 0.00000 MHz from 458.75000(WEST TRANS)
+1*(461.02500)-1*(463.97500)+1*(461.70000)

An analysis of these hits shows that nine are 5th order and four are 3rd order. Typically the lower ordered hits are much more likely to occur. These third order hits are shown here in bold type to facilitate their evaluation. The major concern here is that many of the components here are fundamental transmitted frequencies. Since the elimination of fundamental frequencies means a change in transmitting frequency, we often need to examine other options first. In this situation we next look for frequencies that if isolated will eliminate the likelihood of IM products being generated. In the first two results we observe that the frequency of 461.35000 is common. In the last two the frequency of 461.7000 is common. By providing isolation of these two frequencies we will eliminate these 3 rd order IM products.

Case Study #8

Now using the TAP Intermodulation Reports Generator and sorting the output by order of intermod product in ascending order will quickly bring to our attention those IM products that are of lower order. These are the IM products most likely to be generated. The following is an excerpt from a report using the TAP Intermod Report Generator.
TAP Intermodulation Report
Study Parameters
Task: 03/05/98 06:06PM TAP Intermod Study Setup
Max Combinations: 3
Mode: ALL Selected TX Frequencies
Order From: 1 To 6
Harmonics From: 1 To 9
Ignore TX=RX? No
Sort By: Order
Identify Components By: Frequency
Filtered Intermodulation Report: 8503 Products
151.95500* 0.00000 MHz from 151.95500(BANK IV)
+1*(151.95500)
465.66250 0.01250 MHz from 465.67500(TFMCR05-KV)
-1*(463.95000)+1*(929.61250)
465.68750 0.01250 MHz from 465.67500(TFMCR05-KV)
+1*(929.66250)-1*(463.97500)
466.36250 0.01250 MHz from 466.35000(MOCR04)
-1*(463.20000)+1*(929.56250)
466.98750 0.01250 MHz from 466.97500(MPHONE CR2)
+1*(931.06250)-1*(464.07500)
468.21250 0.01250 MHz from 468.20000(TFCR07)
-1*(461.35000)+1*(929.56250)
468.93750 0.01250 MHz from 468.95000(MOCR03)
+1*(929.61250)-1*(460.67500)
468.98750 0.01250 MHz from 468.97500(MPHONE CR1)
+1*(929.66250)-1*(460.67500)
469.08750 0.01250 MHz from 469.07500(TFMCR07-KV)
+1*(931.06250)-1*(461.97500)
151.94000 0.01500 MHz from 151.95500(BANK IV)
+1*(453.75000)-1*(454.05000)+1*(152.24000)
151.95500* 0.00000 MHz from 151.95500(BANK IV)
-1*(461.55000)+1*(461.02500)+1*(152.48000)
151.96500 0.01000 MHz from 151.95500(BANK IV)
-1*(464.22500)+1*(463.95000)+1*(152.24000)
151.96500 0.01000 MHz from 151.95500(BANK IV)
+1*(453.75000)-1*(454.02500)+1*(152.24000)
151.96500 0.01000 MHz from 151.95500(BANK IV)
-1*(461.97500)+1*(152.24000)+1*(461.70000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)

-1*(887.34000)+1*(454.05000)+1*(889.44000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+1*(883.14000)-1*(881.04000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+1*(883.77000)-1*(881.67000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(452.20000)+2*(454.17500)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+1*(463.95000)+1*(454.17500)-1*(461.97500)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+2*(151.95500)+1*(152.24000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
+1*(454.05000)-1*(461.97500)+1*(464.07500)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(461.55000)+1*(453.75000)+1*(463.95000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(884.19000)+1*(454.05000)+1*(886.29000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(882.93000)+1*(885.03000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(883.56000)+1*(885.66000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(884.82000)+1*(454.05000)+1*(886.92000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(882.30000)+1*(884.40000)+1*(454.05000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(886.71000)+1*(454.05000)+1*(888.81000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(886.08000)+1*(454.05000)+1*(888.18000)
456.15000* 0.00000 MHz from 456.15000(WCNOC/KPL)
-1*(885.45000)+1*(454.05000)+1*(887.55000)
456.16000 0.01000 MHz from 456.15000(WCNOC/KPL)
+1*(885.03000)-1*(880.02000)+1*(451.15000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(881.88000)+1*(885.03000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(881.25000)+1*(884.40000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(885.03000)+1*(454.05000)+1*(888.18000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(885.66000)+1*(454.05000)+1*(888.81000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(883.14000)+1*(454.05000)+1*(886.29000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(884.40000)+1*(454.05000)+1*(887.55000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(454.05000)+1*(892.59000)-1*(889.44000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(883.77000)+1*(454.05000)+1*(886.92000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+2*(454.17500)-1*(451.15000)

457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(454.05000)-1*(886.29000)+1*(889.44000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(454.05000)+1*(891.96000)-1*(888.81000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(152.24000)+2*(152.48000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(884.82000)+1*(887.97000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(884.19000)-1*(881.04000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(882.93000)+1*(886.08000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(884.82000)-1*(881.67000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(884.19000)+1*(887.34000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(888.60000)-1*(885.45000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(883.56000)+1*(886.71000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
+1*(885.45000)-1*(882.30000)+1*(454.05000)
457.20000* 0.00000 MHz from 457.20000(YELLOW CAB)
-1*(882.51000)+1*(885.66000)+1*(454.05000)
457.20500 0.00500 MHz from 457.20000(YELLOW CAB)
-1*(158.70000)+1*(151.95500)+1*(463.95000)
457.21000 0.01000 MHz from 457.20000(YELLOW CAB)
+1*(885.03000)+1*(452.20000)-1*(880.02000)
457.21000 0.01000 MHz from 457.20000(YELLOW CAB)
+1*(886.08000)-1*(880.02000)+1*(451.15000)

The output from the report generator when sorting by order of hit lets us easily see several things. The revelation of a first order hit should be the greatest concern. Hopefully, this is either a data entry error on either transmitting or receiving frequency or a simplex operation. Otherwise, the receiving frequency of 151.95500 MHz is unusable. There are eight second order hits. All of these are in the UHF band. Only with 3rd order hits to we return to the VHF band. To some that might imply that our VHF band is less susceptible to IM product generation. This assumption would not be valid. A review of all the input data, though not shown here, reveals that only one VHF receiving frequency and 3

VHF transmitting frequencies were used at this site. All 133 other frequencies are either UHF or 800 MHz. As in all cases solution to intermodulation product generation is isolation. Apply the techniques discussed throughout this paper to bring about prevention or elimination.

Equipment Used

Spectrum Analyzer – This is a piece of electronic test equipment that, when supplied with an input signal, will graphically plot the amplitude of any signals received at the terminals on the vertical axis with the horizontal axis of the plot being frequency. This is a very important diagnostic tool, if you must locate the actual intermod signal. A highly directional yagi antenna (or sometimes a loop antenna) is the typical receiving device connected to the input to the spectrum analyzer. A small antenna with sufficient cable to reach the spectrum analyzer will permit you to move around the site and point the antenna to specific locations to permit you to triangulate and locate the specific device out of which the intermod is being radiated.

Cavity – A device hooked in series with the RF chain that, when properly tuned, presents a very low insertion loss for its tuned frequency and a much greater loss at frequencies both above and/or below the tuned frequency. This can provide excellent rejection of signals that are different from the frequency for which the cavity has been designed to pass. The most basic filters are built to pass a certain frequency and reject either above or below that frequency. A bandpass filter will pass a specific frequency and reject both above and below that frequency. These bandpass filters can be combined to create a window or groups of filters that pass specific groups of frequencies and reject frequencies outside these specified groups of frequencies. A typical cavity can provide 15-30 dB of isolation while requiring an insertion loss of approximately 0.5 – 3.0 dB. For increased isolation you can cascade the cavities. Other types of filters will block frequencies above or frequencies above the desired frequency.

Circulator / Isolator – A circulator is a three port device which will present a low loss path in one direction (transmitter to antenna) and a high loss path in reverse (antenna to transmitter). Any power trying to enter the output port (antenna) will be "circulated" to a third port, which will supply that signal to an attached load. This provides a very high isolation for the transmitter from any signals sent back from the antenna. Once a load is connected to the appropriate port on the circulator it is then called an isolator. Since most antennas will not have an actual SWR greater than 2.0, the practical power rating on the dissipation load is typically 50% of that of the antenna input power. Single circulator installations can provide approximately 30 dB of isolation with 0.6 dB of insertion loss. Dual circulators can provide approximately 70 dB of isolation with approximately 0.9 dB of insertion loss for the desired frequency. There are three primary reasons to use isolators. 1) It provides reduction of intermod by suppression of signals received in the transmitting antenna and shunting these signals to the dissipation load rather than coupling them back into the transmitter final amplifier. 2) It provides a very stable 50 ohm resistive load into which the transmitter can operate. Most antenna system components have highly reactive impedances rather than resistive. This can cause impedance instability especially when icing on the antenna is present. 3) It provides an expensive fuse for an even more expensive amplifier significantly protecting it from lightning damage.

Duplexer - A device that allows you to transmit and receive simultaneously with the same antenna system. It provides a low loss path from the transmitter output to the antenna at the transmitting frequency and low loss path from the antenna to the receiver input at the receiving frequency. It also provides the receiver input with significant isolation from the transmitter carrier frequency and thereby permits receiving of a very weak signal while simultaneously transmitting a much higher powered signal using a common antenna. A significant benefit is that you need only one antenna. You eliminate the cost to purchase, install and maintain two separate antennas and feed lines. Also, the reduction in the number of antennas on the tower also reduces wind loading on the tower.

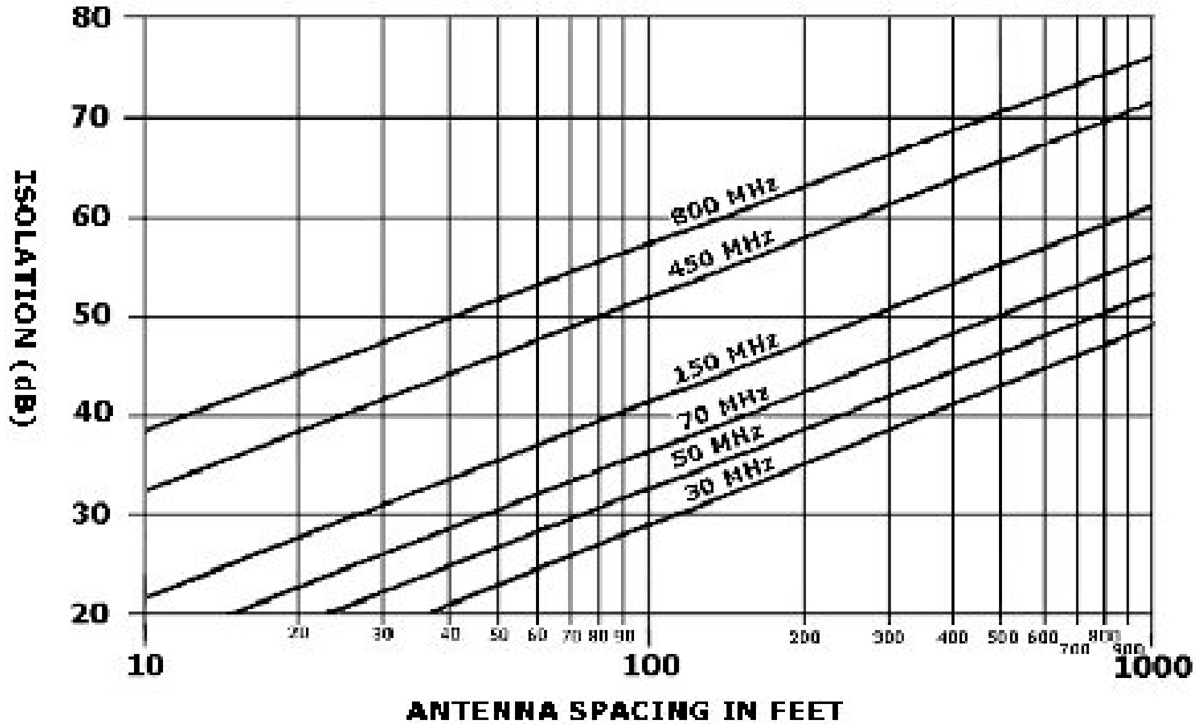
Multicoupler – A device that permits the connection of one receiving antenna to many individual receivers. These devices can be as simple as a passive splitter or as complicated as a box that contains a pre-selector (wide bandpass filter), a wideband amplifier and a number of cascaded splitters.

Resolution and Avoidance of Interference

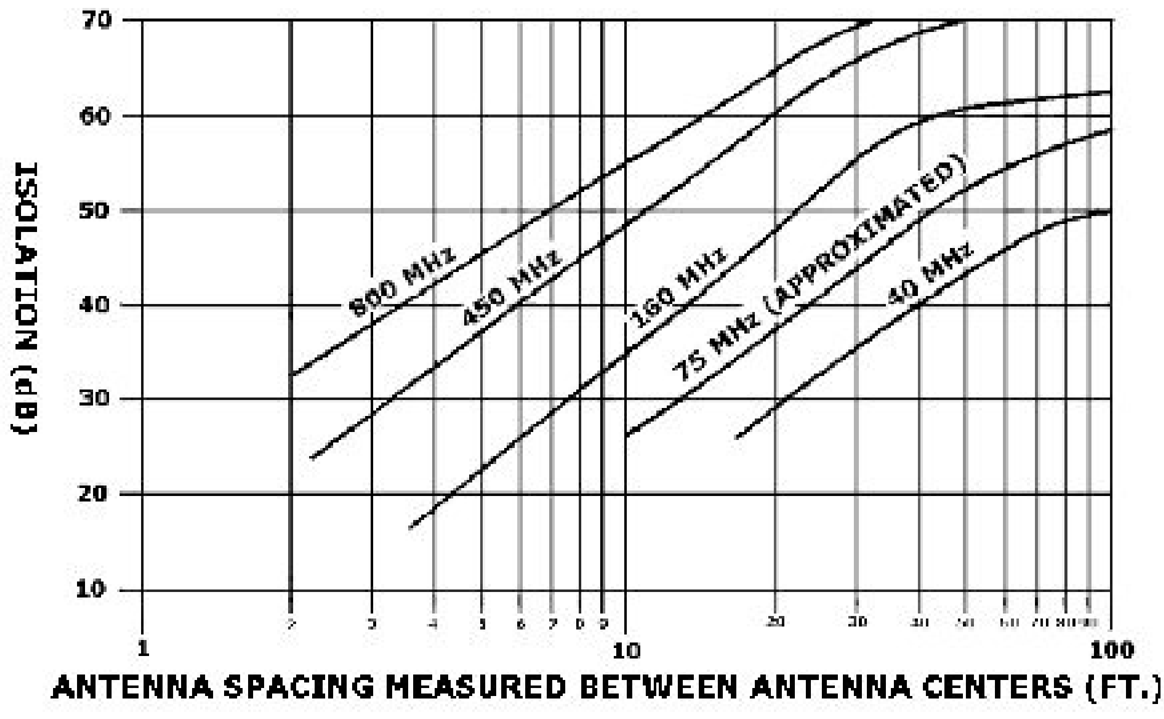
If your work is diagnostic in nature, meaning that you are attempting to solve an existing problem, you will need to identify both the type and actual source of the problem. Listen to the traffic on your system. Listen to the complaints from your system users. Continually assess whether or not you observe any resolution of these symptoms. If your research is preventative in nature you will need a great deal of information on how equipment is to be installed at the site. This pre-screening for potential problems can allow you to take into account the existing filtering already in place in order to assess the likelihood of any potential intermodulation products. You can also make wise filtering and design recommendations prior to placing the system in operation, which will minimize the likelihood of new destructive intermodulation products being generated.

If intermod is present at a site, its aplitude will be eliminated by increased isolation between the components used to generate the product and the equipment in which the product is being generated. If your newly proposed frequencies are components in predicted possible intermod generation, they too must be treated by increasing isolation between the source of participating radiation and the location where the mixing occurs. Also, it should be remembered that the resolution of problems that do materialize is based on well-established techniques, which have been thoroughly proven. The vast majority of such problems are remedied by the use of relatively simple filters and traps installed on the appropriate equipment and with proper grounding techniques. Spurious radiation products, which are generated in the input stage of a receiver, may be suppressed by the use of a notch filter(s) at the input terminals to attenuate the undesired components of other frequencies which contribute to the spurious product. Alternately, when a large number of components are involved, or when the exact nature of the interfering signals is not clearly defined, a narrow band pass filter may be used to selectively pass only the desired received frequency. Likewise, spurious radiation components generated in the output of transmitting equipment may be reduced to levels which to not cause objectionable interference by the use of notch and/or band pass filters on the transmitter output. The careful analysis of any problem which might arise will allow the logical application of the principles of good engineering practice. This isolation (attenuation of an undesired signal to prevent its mixing) can be achieved in one or more ways. Increasing the physical separation between antennas and the judicious use of appropriate filtering apparatus are the most common methods of treatment. Increased vertical separation will be much more efficient than increased horizontal antenna separation. This is due to the fact that most antennas have substantial nulls in their radiation patterns immediately above and below. It is typical that for a given desired isolation between two antennas at least eight times the vertical separation distance is required if you wish to achieve the same isolation by horizontal separation. Also, for a fixed separation between antennas, isolation will be higher for a higher frequency. Typically measured isolations are shown below in the following graphs.

ATTENUATION PROVIDED BY HORIZONTAL SEPARATION OF DIPOLE ANTENNAS



ATTENUATION PROVIDED BY VERTICAL SEPARATION OF DIPOLE ANTENNAS



Receiver Desensitization

The most common source of interference problems at multi-user sites is the desensitization of receivers due to the overload of their front end detection circuits by the presence of high-levels of the offending carrier signal. The high powered signal saturates the circuitry, driving the signal levels in the affected components beyond their normal operating range, so that normal variations from the modulation of the desired received signal cannot be reliably detected. This type of problem is a function of the frequency separation of the offending signal and the frequency desired to be received, the physical separation between the transmitting antenna and the receiving antenna, and the power levels involved.

Susceptibility of Equipment

Another common contributing factor in cases of mutual interference between electronic equipment at shared transmit and receive sites is the general condition and the quality of installation of the existing and new equipment. Ungrounded or improperly grounded metal buildings, chain link fences, plumbing, supporting tower sections, sheet metal roofing, etc. can result in substantial problems of reflection, absorption, and reradiation of fundamentals as well as harmonic signals producing destructive spurious radiation. All such elements at any transmitter site location should be carefully bonded together and grounded to minimize such possibilities. Likewise, the electrical power supply wiring at the site must be properly installed with mechanically secure connections and the neutral wire of all fixtures, conduits and other non-current carrying metal parts be securely bonded and grounded to an adequate low-impedance earth ground.

The most critical components in reducing susceptibility of equipment are obviously the electronic equipment itself. All equipment must be properly adjusted, shielded and grounded to reduce the possibility of stray radiation either radiating from the equipment or penetrating into the equipment. All portions of coaxial cable connecting transmit/receive equipment with antennas should be kept as short as possible, installed directly from the antenna to the respective equipment, and properly supported, shielded and grounded. All mechanical connections between cables, antenna, terminals, plugs and connectors should be mechanically tight. All equipment covers and other shielding features should be in place and fastened securely and firmly connected to ground. Harmful interference resulting from equipment susceptibility problems, improper grounding, inadequate or missing shielding, etc., can generally be remedied by the application of simple repair, alignment and preventative maintenance procedures. Any reduction in susceptibility to interference will also maximize performance of the equipment. Some installations actually are placed inside a screened (or rf shielded) enclosure to provide maximum isolation of undesired external ambient rf levels.

Benchmark your baseline noise with spectrum analyzer. When you are trying to locate the source of the IM product, is a good idea to sniff out the exact location of generated intermod with a highly directional antenna (sometimes a yagi or loop antenna) connected to the input of a spectrum analyzer while observing the received IM product on the screen. With sufficient cable you can move around the site, pointing the antenna toward various pieces of building structure, towers and antennas to determine the precise source of the generated intermod product. The antenna suitable for sniffing could be a small dish, a yagi or a loop antenna, depending upon the frequency and level of the signal. In order to find a suitable solution to the intermod, you must locate the source where it is being generated and radiated. Once that is known, you can then strategize how to increase isolation between that source of generation and the level of the input signals that are used to generate the intermod.

Transmitter Generated

In order to reduce transmitter generated intermod, increase isolation between the transmitting antennas. This can be done with a great deal of horizontal separation or much more efficiently with increased vertical separation. See the graphs above to quantify levels of isolation for various physical separations and frequencies. If not already installed, place isolators on the transmitter outputs. Dual isolators will substantially attenuate signals received via the transmitting antenna and preclude their coupling back into the transmitter final amplifier. Another excellent treatment is to combine all transmitter outputs into one single transmission line and antenna. The filtering to do this will provide excellent isolation of the combined transmitters from each other and also eliminate the likelihood of any of these transmitted frequencies being reintroduced and cause the possible generation of intermod. This will also substantially shift the construction costs from many antennas and transmission lines to the purchase of a combining system. While not necessarily cheaper, the system will be much less susceptible to IM problems.

Once you can identify which frequencies are actually combining to generate the intermod, even if you cannot ascertain the location where it is being generated, one of the simplest but least desired solutions is the reduction of one or more of the participating frequency's ERP. Sometimes, the installation of a directional antenna for suppression of undesired receiving signal is a good solution. In some cases you can even receive a substantial level of undesired signal from your antenna and mix it out of phase with a signal from a second very high gain reception antenna in order to suppress undesired signal. (This also works well for suppression of co-channel interference.) If the intermodulation product is generated from a harmonic, eliminate the harmonic emission from the offending transmitter first. If it is adequately suppressed at the transmitter output and is still measurable with your sniffing antenna, then this harmonic is being generated externally and the location where this is occurring must be located. If the product is being generated from a combination with a fundamental frequency, you might be forced to eliminate the fundamental frequency by changing that frequency.

Avoidance of preventable stray coupling can save a lot of grief. Careful bonding of all the radio equipment to a common ground will reduce noise in the system. Always use shielded cables for audio and control wiring to avoid the introduction of stray RF into the equipment enclosures. It is also wise to install all AC and DC power to equipment inside runs of conduit. Sometimes toroidal chokes are used on the AC input just outside the cable entrances into the enclosures. Coaxial feed line should not be tightly bundled together either inside the building or up the tower. You should secure the cables with cable clamps, providing spacing of at least a few centimeters between parallel runs. Also, it is important to provide a much greater separation between transmitting coaxial cables and those used for receiving. If possible, enter the equipment with both cables at separate and isolated entry points into the cabinets.

Receiver Generated

If the IM product is being generated within the receiver you will need to reduce high levels of undesired signals into receiver. You might install either notch (for the offending frequency) or bandpass filters (tuned to the desired received frequency) in-line with the receiving antenna. Improved receiver shielding with proper grounding can also minimize susceptibility. Screening the entire room with copper screening or even chicken wire, properly bonded together and grounded, will also help reduce the rf level present for all the equipment inside the screened room.

External Generated

Use only non-corrosive antenna mounting hardware. Keep all hardware (including tower bolts) tightened. Remove unnecessary metal from the transmitter site. Use proper grounding, not only for the equipment, but also for all metal structures at the site. Ground metal fencing at the site as well. Better yet, avoid the use of metal fences and posts all together. Wooden fencing will not present any problems of creating intermod. Use antennas with welded construction rather than nut and bolt fasteners.

Plan Ahead

Avoid mounting any antenna where its near field will be likely to induce a signal into tower guy wires. This near field is generally approximately within ¼ wavelength of the frequency used. This can be calculated by the following equation: Wavelength in meters = 300/ Frequency in MHz. If it is absolutely necessary to mount an antenna within this space, it is helpful to replace the steel guy wires with fiberglass guy wires at least within a few wavelengths of the antenna. This fiberglass guying cable will work well very high in the air because the cables are very strong, but never use this type of guy wire material anywhere near the ground. A minor grass fire can melt the fiberglass and thereby cause the tower to fall!

Intermod Etiquette

Any applicant for new radio transmitting facilities should recognize the potential for creating interfering intermodulation products on some frequencies, especially should a direct hit occur. The applicant should also be aware that existing intermodulation products might have already rendered an otherwise unused receive frequency unusable, unless treatment is applied to existing radio equipment. A check of the real-time RF spectrum will normally reveal any pre-existing interference problems. Other intermodulation products not directly on the protected frequencies, but within the protected band-width of existing receivers, will also have to be treated.

Special care will need to be exercised during the installation and testing of the proposed facilities to minimize the introduction of any harmful interference caused by the new equipment. Appropriate filtering measures must be taken by the new system operator to remedy problems that develop as a direct result of the installation of the new equipment. Most site managers and the required site leases will generally obligate the new system operator to assume the responsibility to cure any new intermodulation products that cause objectionable interference. It is important that the new facility be installed in complete compliance with existing federal, state and local regulations including the National Electric Code and in accordance with the principles of good engineering practice. This must be done in order to minimize the possibility of objection-able interference between the new system and existing equipment presently in use at the site. In the event that objectionable interference is experienced, the new system will generally be expected to cooperate to the fullest extent possible to deter-mine the cause of the interference. Observing the interference problems through the use of a spectrum analyzer in conjunction with directional antenna equipment is required to precisely isolate the exact source of the problem. It is common practice to expect the new user to assist in determining the best solution to any interference problems experienced as a direct result of the new installation. He will generally bear the financial responsibility for correction of any such problems. He is also often expected to assist other users at the site in locating problems of susceptibility in their equipment, as well as providing recommended solutions.

If you are anticipating permission to use a certain frequency that has the possible participation in the generation of new intermodulation products, it is wise to thoroughly test the proposed new operation with the cooperation of those possibly subject to any new interference, before you place the system into full operation.

It is also true that some existing operations are so poorly installed that their susceptibility is exceedingly difficult to eliminate without substantial modification of their installation and equipment. It can be quite expensive to modify existing installations to bring them up to proper installation standards. It is wise to examine all these important circumstances before agreeing to absolute liability to cure problems. New equipment should be installed in accordance with good engineering practice, as described above, in order to minimize the possibilities of the new equipment contributing to any interference problems.