

CO-SITED FM TRANSMISSION SYSTEMS

Richard J. Fry
rfry@adams.net

Introduction Two or more FM stations can share the same or nearby sites to take advantage of favorable conditions there. These conditions can include factors such as zoning, existence of FAA clearances, a desirable geographic location, and the use of existing or common antennas, towers and transmitter buildings. However the presence of other transmitting facilities on that site or nearby usually requires RF filters to be installed at the output of each transmitter in the system.

Filters control the generation of RF intermodulation (IM) products arising from energy coupled between the antennas, or through the transmitter combining systems. The primary IM product is generated from the second harmonic of each transmitter mixing in that transmitter with the fundamentals of all other transmitters in the system.

As an example, when two co-sited stations are on frequencies 1.4MHz apart, the strongest IM products will be generated 1.4MHz below the lower carrier frequency and 1.4MHz above the higher carrier frequency, or $2F_{(LOW)} - F_{(HIGH)}$ and $2F_{(HIGH)} - F_{(LOW)}$. For an ERP of 5kW or more, the FCC requires all spurious emissions on frequencies >600kHz from the carrier frequency of FM broadcast stations to be attenuated at least 80dB below the unmodulated carrier.

Filter performance specification depends on a number of factors, including...

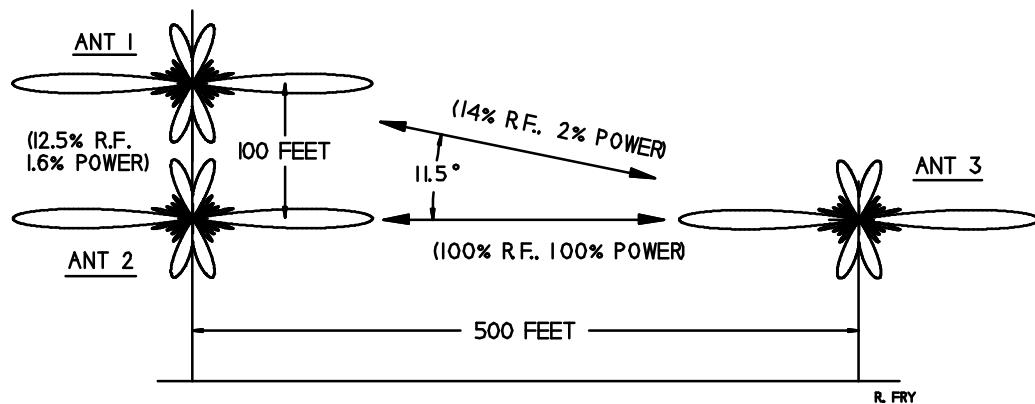
1. Frequency separation
2. Antenna azimuth and elevation patterns (including the affect of the mounting structure)
3. Polarization
4. Physical separation of antennas
5. Radiated powers
6. Transmitter output stage characteristics
7. Number of transmitters per antenna
8. Affect on transmitter performance characteristics

Some of these factors are discussed in more detail in the following sections.

SYSTEM CONFIGURATIONS

Multiple Antennas Separate antennas often are used when only a few stations share a site. These antennas can be mounted on a single tower, or on adjacent towers. Figure 1 shows how the antennas might be arranged for a three-station site. Note that antenna three in the illustration will have less coupling into antenna one than it has into antenna two, even though antenna three is about the same distance from antennas one and two. This is due to the reduced relative fields of the elevation patterns of antennas one and three toward each other, for this installation geometry. Antenna elevation patterns and the horizontal and vertical separation between antennas have a strong influence on the amount of filtering required for co-sited broadcast stations.

Figure 1. MUTUAL COUPLING BETWEEN ADJACENT ANTENNAS AS A SOURCE FOR RF INTERMODULATION



(Free space patterns of six-bay rototiller element arrays at one wavelength vertical bay spacing)
Filtering for this configuration typically is achieved either with bandpass or notch filters. Figure 2 shows some of the filtering considerations for sites where each transmitter has its own antenna.

Figure 2. SPECTRUM FILTERING CONSIDERATIONS FOR CO-SITED FM STATIONS

TX FM OUTPUT	SPECTRUM. NOTE: FILTERS NORMALLY NEEDED AT F1 AND F2 TRANSMITTERS	EXTERNAL SIGNAL DUE TO COUPLING BY ADJACENT ANTENNA	ADVANTAGE	DISADVANTAGE
<p>PRIMARY INTERMODULATION PRODUCT OF THE TWO FREQUENCIES AFTER MIXING IN THE PA STAGE OF F1 TRANSMITTER</p> <p>-80dBc FCC SPEC</p> <p>IM PRODUCT</p> <p>MAIN SIGNAL</p> <p>INTERFERING SIGNAL</p> <p>2 x F1 - F2 F1 F2</p>	<p>SPECIMEN. NOTE: FILTERS NORMALLY NEEDED AT F1 AND F2 TRANSMITTERS</p>	<p>NO FILTER</p>	<p>ZERO HARDWARE COST.</p>	<p>RISK OF FCC CITATION. INTERFERENCE SOURCE TO OTHER BROADCAST AND/OR PUBLIC SAFETY STATIONS.</p>
<p>IM PRODUCT >-80dBc DUE FILTER REMOVING MOST OF THE F2 SIGNAL BEFORE IT CAN MIX IN THE F1 TX</p> <p>NOTCH FILTER RESPONSE</p> <p>2 x F1 - F2 F1 F2</p>	<p>NOTCH FILTER</p>	<p>LEAST EXPENSIVE FOR TWO-STATION SITE. NEGLIGIBLE INSERTION LOSS.</p>	<p>NO PROTECTION FOR ADDITIONAL STATIONS (FUTURE) HOWEVER NEW NOTCH FILTERS CAN BE ADDED TO SYSTEM.</p>	
<p>IM PRODUCT >-80dBc DUE FILTER REDUCING THE LEVEL OF THE F2 SIGNAL BEFORE MIXING AND FILTER AFFECT ON THE IM PRODUCT ITSELF</p> <p>BANDPASS FILTER RESPONSE</p> <p>2 x F1 - F2 F1 F2</p>	<p>BANDPASS FILTER</p>	<p>A SINGLE MULTI-CAVITY BAND- PASS FILTER CAN PROTECT THE TRANSMIT- TER FROM PRODUCING IM PRODUCTS IN EVENT FUTURE FM TRANSMITTERS JOIN THE SITE.</p>	<p>MORE EXPENSIVE FOR CLOSE FREQUENCY SPACINGS (2 to 3X MORE EXPENSIVE). HIGHER INSERTION LOSS: CAN LOSE 10-12% OF TRANSMITTER POWER WHICH IS CONVERTED TO HEAT IN THE TX ROOM.</p>	

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Filter Specifications Important criteria in selecting filters are their insertion loss and group delay characteristics across the operating channel, and their rejection characteristics across the

channels of the co-sited stations. Insertion loss produces heat in the transmitter building, and calls for higher output power and higher operating costs for the transmitter to overcome filter losses. Low, and symmetrical values of group delay across the operating channel are important to maintain low stereo and subcarrier crosstalk. The requirement for symmetrical group delay can eliminate the use of notch filters for close frequency separations (about 1MHz or less). Ideally, group delay across the operating channel should not exceed 30ns, if symmetrical, or about 5ns if asymmetrical. Typical values of insertion loss across the operating channel are 0.05dB for notch filters, and 0.2dB to 0.4dB for bandpass filters. A value of 0.4dB doesn't sound too significant, but in fact, transmitter output has to be increased by almost 9% to compensate for that 0.4dB loss.

System Optimization Both notch and bandpass filters provide a non-constant impedance to the associated transmitter, i.e., they present a high mismatch to the transmitter in the region of the spectrum where they reject external signals. Such narrowband loads sometimes will affect a transmitter's overall modulation performance and stability. In these cases, optimizing the length of the transmission line between the output of the transmitter and the input to the filter will permit normal operation. This length is determined experimentally, following installation of the system, by observing the output spectrum of the transmitter for normal performance over the expected range of output powers and tuning/loading conditions.

System Design The amount of filtering needed for each transmitter can be estimated by considering the eight factors listed on page one. Unfortunately, both the amount of antenna coupling and the conversion loss characteristics of the transmitter that bear on producing IM products often are not well known, so the filter specification is, at best, only approximate.

Conversion loss may be defined as the reduction in the amplitude of the transmitters 2F1-F2 IM product to the amplitude of the interfering signal that produced it. A typical value of conversion (or "turnaround") loss for Harris single-tube FM transmitters is 1.5dB/MHz of frequency separation between the transmitter carrier frequency and that of the external carrier(s). Conversion loss for Harris Platinum and Platinum-Z series transmitters¹ is approximately 12 to 15dB, regardless of frequency separation. Transmitter conversion loss is important in that it directly reduces the amount of isolation required by an external filter, which can reduce its insertion loss, size, and cost.

Antenna and transmitter manufacturers typically will work with the site designers to determine an expected filter value, but in the final analysis the broadcaster must provide whatever filtering is required. Sometimes the estimated value is not sufficient, and additional filtering must be provided when the measured IM performance of the installed system so directs.

Common Antenna When only two or three stations are co-sited, it may be practical to use a broadband version of a "rototiller" antenna, or equivalent sidemount design. The transmitters must be combined in a channel combiner or multiplexer that provides the isolation needed between the transmitters, while passing their output signals to a single output port with minimum power loss or other degradation. Filtering requirements are more rigorous because there is no space and pattern decoupling in a common antenna, as there is when separate antennas are used.

Combiner Types Two main combiner designs are used: a branch or "tee" type (sometimes called starpoint) combiner, and a constant impedance design. Branch combiners use either notch or bandpass filters (sometimes both in combination) to isolate each transmitter from the

¹ An exception being the Z2, 2kW Z-series transmitter, which is about 3dB.

others in the system. Constant impedance combiners typically use an arrangement of two banks of bandpass filters connected between two 3dB hybrids. Some important features of each are summarized in Table 1 below.

Table 1: COMPARISON OF BRANCH AND CONSTANT IMPEDANCE COMBINERS

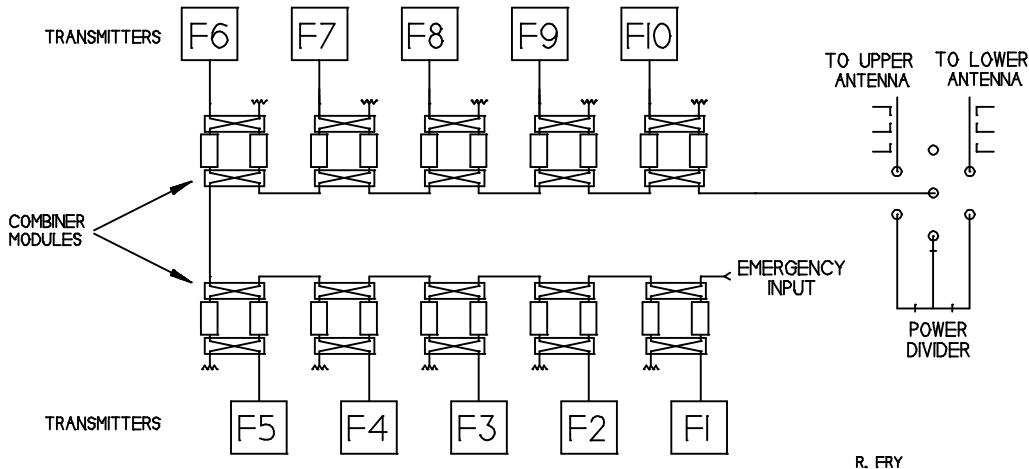
FEATURE	BRANCH TYPE	CONSTANT IMPEDANCE TYPE
Cost, for a given frequency separation	Lower	Higher
Expandability, if future stations join the system	Poor	Good
Floor space area requirements	Lower	Higher
Possible affect on transmitter performance, stability etc	May require system optimization	Little affect on transmitter performance; optimization not required

FM combiners and filters are physically large — larger than most FM transmitters themselves. Suitable space for the combiner must be planned for in the design of the transmitter building. Filter and combiner manufacturers and suppliers typically have installation planning guides that will be provided on request.

Master Antennas Co-sited groups of more than about three stations often use a single, broadband cavity-backed radiator or other “panel” type of FM transmitting antenna commonly described as a master antenna. These antennas have an additional advantage in that they can provide more omnidirectional radiation patterns, and much better parity between the horizontally and vertically polarized radiation patterns (lower axial ratio) than achievable in a typical single station antenna.

The design of the master FM antenna can include separate upper and lower antenna sections with separate transmission lines from the combiner room. With the required patching, this enables all stations to use either half of the antenna at reduced power to allow maintenance of the other half, as shown in Figure 3.

Figure 3: MASTER FM ANTENNA SYSTEM



Other system enhancements can include patch panel bypass of each combiner module to enable service of the module, and special RF monitoring to evaluate RF system performance when multiple carriers are present (the usual in-line watchdog type of system is not designed for multiple carriers).

As most master FM antenna systems are located in the larger markets where best system performance is mandated, the combiners for these antennas are almost always of the constant-impedance type.

There are numerous examples where eight to ten FM stations have joined financial and engineering resources to build a common transmitter building, tower and antenna. The cost per user of the Master FM site can be very favorable compared to the cost of a single user to provide an equivalent facility independently. However the process of getting all stations together to agree on and fund a master antenna project sometimes can be a challenge for station managers and engineers.

Summary It can be very advantageous to co-locate several FM transmitter and antenna systems, however due care must be used to assure that the site meets FCC requirements for suppression of spurious signals that can be generated at such sites. Various appropriate types of antennas and filter systems are available for co-located FM systems. The technology is well-proven and reliable, and such sites are gaining in popularity with the consolidation of station ownership in a given market, and when the FM antenna tower space is being reassigned to other uses by the tower owner.

But whether separate or common antennas are used, it is advisable to employ a consulting engineering firm to take overall responsibility for the system design and performance. Many times their experience in previous projects can reduce the overall cost of new projects by developing practical specifications for them. This factor can be very important in the overall success of the project.
