Shared Use of AM Sites

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Abstract

With land in and around urbanized areas becoming more and more valuable, AM broadcasters often have a difficult time locating and holding onto parcels of land large enough to support their towers and ground systems. Finding adequate close-in land for a directional array can be a real challenge. To make matters worse, today's regulatory climate and neighborhood objections many times make erecting towers a difficult task. Sharing an established site between stations is an alternative that can provide the site owner with a significant income stream while at the same time alleviating all the problems of locating and developing a new site for the tenant. In this paper, I will discuss the issues relevant to sharing directional and non-directional antenna sites between two or more AM stations. This discussion will include multiplexer design and construction as well as practical considerations of shared site use.

1.0 Introduction

There was a time when it was not a problem to erect a tower or array for a broadcast or communications site. As the number of broadcast stations, two-way and paging systems grew, towers began to dot the landscape, always seeking the high ground while avoiding the airports.

Those days are long gone. With often-unfounded concerns about the effects of RF radiation on those living near broadcast and communications towers becoming the topic of zoning, planning and city council meetings, local regulations are in place in many locations that make it very difficult if not impossible to erect a tower. Everyone wants good broadcast reception and good cellular/PCS service, but "Not In My Back Yard" (NIMBY) has become the watchword regarding new tower construction all across the nation.

As a result, there has never been a time when there was more demand for tower space. While technology has taken off like a skyrocket in the past decade and most everyone you see is carrying a pager or wireless phone, keeping up with demand for antenna space has become perhaps *the* biggest challenge for those providing such service.

The number of broadcast stations has also increased. DTV and LPTV have placed significant demands on the supply of vertical real estate. AM stations, particularly directional AMs, are quite often real estate hogs. Urban sprawl and development have, in many cases, made the once valueless bottom land on which AM arrays are sometimes located worth much more than the stations themselves, pushing the AM stations out and forcing them to seek new sites.

"Co-location" is a word often heard at planning commission and city council meetings. To these regulatory bodies, it represents a simple solution to the needs of the broadcaster/communications service and the desires of constituents — using an existing tower site, one which presumable already meets all regulatory requirements or is grandfathered, one which residents have already become accustomed to, for the new service. Unfortunately, co-location is not as easy as local governing bodies would like to think.

While sharing of towers is nothing new, it has gone from being a means of generating revenue for the tower owner to a necessity for broadcasters, paging and wireless companies. Large companies such as American Tower Systems, Lodestar, Pinnacle and others have created an entire new industry out of tower construction and leasing.

In this paper, the options broadcasters have where it comes to shared use of towers will be discussed. The discussion will examine both sides of the equation, the viewpoints of both tower owner and tenant, anticipating the possible problems and offering ways to head them off. The rights and responsibilities of both tower owner and tenant will also be dealt with. Some of the main topics will be diplexing (both AM and FM) and shared use of AM towers by other services.

2.0 AM-AM Co-Location

Because of the long wavelength, there are many aspects to an AM co-location that must be considered. Unlike FM and TV, one cannot simply hang one's AM antenna on the side of an existing tower and turn on the transmitter.

Perhaps the most difficult co-location case is the sharing of a single tower or directional array between two or more AM stations.

There are three things that must be considered carefully when first evaluating an AM site for co-location. Frequency spacing between stations, electrical height and location. If any of these is unacceptable, move on.

2.1 Frequency Spacing

Most engineers consider 120 kHz to be the lower limit for diplexing multiple AM stations together. Spacing any closer than that requires ultra-tight filtering that results in narrow bandwidth and high losses in the diplexer. Design of a diplexing system is difficult and operationally the stations probably won't sound very good.

2.2 Tower Height

The electrical height of an AM radiator determines efficiency. If a tower is too short, it will be inefficient, the resistance will be low and losses will be high. Radiation at high vertical angles may be excessive from electrically short towers, making them unacceptable for nighttime operation.

Towers with electrical heights in the 75- to 180-degree range will produce acceptable results in most cases. Shorter towers will have low base resistances and higher losses. Taller towers may be difficult to match and have high reactive components that degrade diplexer performance.

Keep in mind that efficiency of the radiator and protection factors for co- and adjacent-channel stations determines how much power can be authorized from a particular site. Taller radiators are generally more efficient and will produce more radiated field for a given amount of input power. While efficiency is desirable from an economic standpoint, station owners and managers often have a hard time understanding that in some cases, less is more.

2.3 Location

It is said that the three most important factors in real estate are location, location and location. That also goes for transmitter sites, AM or otherwise.

The question that must be answered is, will the proposed facility produce the coverage of the desired area with the power permissible from that site? To determine this, it will be necessary to first run day and night allocation studies from the proposed site, compute the permissible radiation and compute the day and night coverage to see if both the FCC minimum community of license coverage and the performance goals of the station ownership are met.

Unlike FM where spacing tables determine site allocation suitability, the situation is much more complex with AM stations. Both groundwave and skywave radiation must be considered in the allocation study. The primary variables are frequency, vertical radiation characteristics of the antenna and ground conductivity.

If measured conductivity data exists for the proposed site or the sites of any of the nearby co- and adjacent-channel stations considered in the allocation studies, it must be used. It may even be beneficial to make some conductivity measurements for the allocation studies or performance evaluation.

If the proposed site will work from an allocation and performance standpoint, proceed with the evaluation; otherwise, move on.

All this may seem like an impossible combination to find, that co-location probably isn't worth even looking into. While it is labor intensive and time consuming, it fortunately is usually not as hard as it seems.

2.4 Owner Considerations

One other big factor is the willingness of the tower owner, who is sometimes a competitor, to share his tower and site. One might think that the guy across town wouldn't want to do anything to help his competitor. Money talks, however, and adding a few hundred or a few thousand dollars to the top line every month is often an attractive, virtually effortless way to improve station cashflow. In many cases, the site owner will be willing to at least discuss co-location.

2.5 Neighborhood Considerations

AM towers that are located in or near residential or commercial areas quite often have a tenuous relationship with the neighbors. Telephone interference is most often the problem. In residential areas, RF radiation concerns are sometimes a touchy issue (whether or not they are a real factor).

In some cases, a neighborhood agreement may exist that governs what can and cannot be done at a particular site. Where no neighborhood agreement exists, neighbors may turn out in significant numbers at local governing body meetings to oppose the co-location. This can hold up a building permit or even result in an order to stop work at the site.

Neighborhood factors should be carefully investigated and weighed before deciding to proceed with co-location at a particular site.

3.0 Diplexer Fundamentals

To many, an AM diplexer is a mysterious, sometimes spooky device full of coils and capacitors that "sing" when modulation is applied. The reality is that a diplexer is nothing more that a frequency-selective voltage divider. On the reject frequency, the series element presents a high impedance while the shunt presents a low impedance. On the pass frequency, the opposite is true — the series element presents a low impedance while the shunt presents a high impedance. The equivalent circuit can be drawn very simply using two resistors.

Most diplexer designs make the most economical use of components and space to minimize losses and costs as well as to maximize bandwidth. They do this in the series traps by parallel-resonating the residual reactance on the reject frequency with a coil or capacitor. This gives the trap a low impedance on the pass frequency and a high impedance on the reject, using only three components. In the shunt traps, the opposite is true — the residual reactance on the pass frequency is parallel resonated with a coil or capacitor, giving the trap a high impedance on the pass frequency and a low impedance on the reject. Figure 1 shows a typical diplexer circuit.

While there is an infinite number of component combinations that will produce series resonance, practically speaking, the number of combinations is limited by available parts. The desired Q of the circuit further limits the design. Traps with too high a Q store a lot of energy. This can result in higher circulating currents and thus higher losses. A good design engineer will find a reasonable balance between loss, rejection, cost and bandwidth that makes use of commonly available parts.

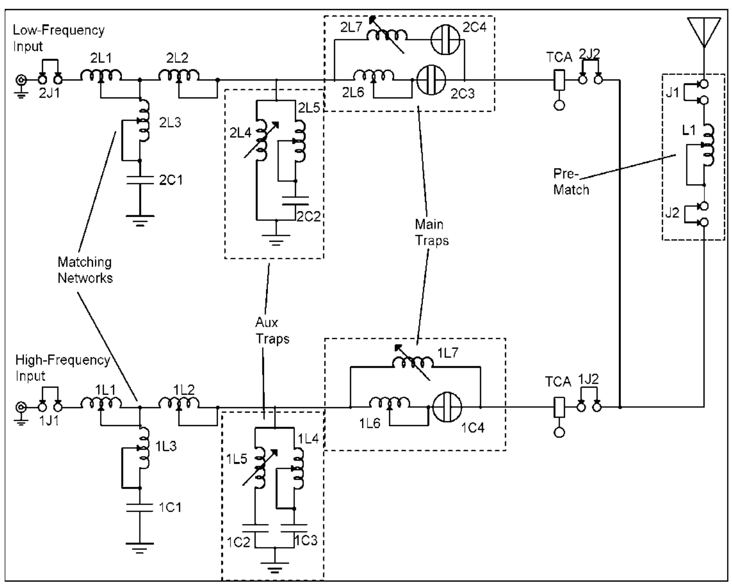

Figure 1

3.1 Diplexing on DA Elements

It is certainly possible to utilize one element of a directional array as a diplexed non-directional radiator. To do this, it is necessary to install filters at the towers that are not used in addition to the regular pass/reject filters at the common driven element. Whether these filters provide for floating (open-circuiting), grounding (short-circuiting) or detuning the unused towers on the ND frequency is usually determined by the tower height. An unused tower that is close to 90 electrical degrees high can most often simply be floated on the ND frequency. A 180-degree tower would probably be shorted. Towers of other heights may require a detuning component to control the current flow on the unused tower on the ND frequency.

It is also sometimes possible to use some or all the elements in one station's directional array to create a directional pattern for another station. Such joint DA use should certainly be considered in some circumstances. A separate set of diplex filters must be installed at each tower base and at towers unused by one or both stations for different patterns.

One other oft-forgotten (until late in the project, anyway) requirement for diplexing with a directional station is the installation of pass/reject filters in the antenna monitor. The monitor will have to be sent back to the manufacturer for this, as after filter installation, he must recertify the monitor's accuracy.

Unlike single-frequency antenna tuning units (ATUs) which are often constructed on open frame chassis with little or no shielding from other components, diplex filters must be well shielded from other components and filters in the system. This typically means that each filter must be constructed in its own shielded enclosure. Sometimes this means constructing the filter in a metal box and inserting that box into another, common metal housing. Other times it may mean placing the filter in a completely separate metal enclosure. Figure 2 is a photo showing the interior of a diplexer cabinet with compartmentalized for each trap.

The designer will determine the configuration and layout of the diplexer after he completes the electrical design and examines the physical layout of the site.

3.2 Diplexer Design Preparation

Figure 2

The design engineer will need a good deal of information before he can proceed with planning a diplexer design. The station engineer will have to provide this information for him or else pay him a premium to come to the site and gather the information himself.

Accuracy is everything. Mistakes at this stage have a big impact on cost and will cause delays later in the project. Below is a list of some of the information the design engineer will need to begin either a directional or non-directional diplexer design:

C Self-impedance measurements on both frequencies for the driven element, and driving point impedance measurements on all directional elements in the array for all modes of operation at the directional frequency. If an impedance bridge, oscillator and detector are available, these measurements can be made by the station engineer. For self-impedance measurements, disconnect all ATU components from the tower before measuring. If part of a directional array, the design engineer will advise whether to float (open) or short the other towers in the array during the self-impedance measurement. Center as well as sideband frequency (± 10 kHz) self-impedance measurements should be made. For driving point impedances, after inserting the bridge, it is necessary to carefully readjust the phasor for the proper phase and ratio values on the antenna monitor, thus tuning out the insertion effect of the bridge. All reactance readings should be corrected for frequency.

C Base currents on all directional elements. These should be measured with a toroidal or thermocouple ammeter of known accuracy.

C Power of both stations for each mode of operation.

C Directional antenna parameters (phase, field ratios and base current ratios) of the directional station for each mode of operation.

C Schematic diagrams of all existing antenna tuning units. If the original schematics are unavailable, the station engineer can sketch “as-built” schematics by carefully looking at and tracing out the circuit, identifying the values of all components as best as can be done. Capacitors will have values and ratings stamped on them; coils will usually have a manufacturer’s ID plate with the coil value. Copies of any field notes or other information on the installation and tune-up that can be found should be provided.

C A complete and accurate drawing of the site layout. Particular attention should be paid to the vicinity of the tower bases, tuning houses or tuning units and drawings should either be made to scale or give dimensions. Photos are also helpful along with the drawings. All this information is critical in planning the mechanical construction and layout of the diplexer.

The design engineer may ask for more information after he reviews the first set of data you send him. His goal is to create a diplexer that will be transparent to both the high and low frequency transmitters, provide excellent isolation, prevent the creation of intermodulation (IM) products and provide for the safety of those working at the site. How much success he will achieve largely depends on the quality and accuracy of the information provided to him.

3.3 Multiple Station Co-Location

It is possible to combine three or even four AM stations into one antenna. In areas where tower sites are few (such as Hawaii), it is not uncommon to find several stations all sharing one antenna. Adding additional stations simply means adding additional filters for each station. Losses go up and bandwidth often narrows, but practical compromises can often be reached. Voltages across insulators and elsewhere can become quite high when combining multiple stations, so concessions may have to be made.

3.4 Diplexer Installation

AM diplexing and multiplexing equipment may come in many configurations, but most modern equipment is constructed in individual weatherproof cabinets with a different cabinet for each station. Each cabinet will typically contain two or more compartments, one compartment for each trap and a separate compartment for the tuning/matching components.

Like most antenna tuning units, each cabinet will typically have two connection points: a transmission line input and an insulated RF output. Cabinets should be laid out so that the RF outputs can be easily connected together with tubing. The point where the two (or more) RF outputs tie together is referred to as the "diplex point," as RF currents and voltages for all frequencies being combined will be present.

If a pre-match cabinet is used, it will not have a transmission line input but rather an insulated RF input and output. The pre-match should be positioned so that it can be installed between the diplex point and the tower. Figure 3 is a photo of a typical diplex point connecting two diplexer cabinets together and to the pre-match cabinet. Figure 4 is a photo showing a pre-match cabinet and its tower feed.

As shown in Figure 4, it is a good idea to wind a single turn in the feed tubing

Figure 3

between the diplex point or pre-match (if used) and the tower. This is a lightning protection measure that makes the path from the tower back through the diplexer a higher impedance, diverting the lightning discharge to the path across the ball gap across the tower base instead.

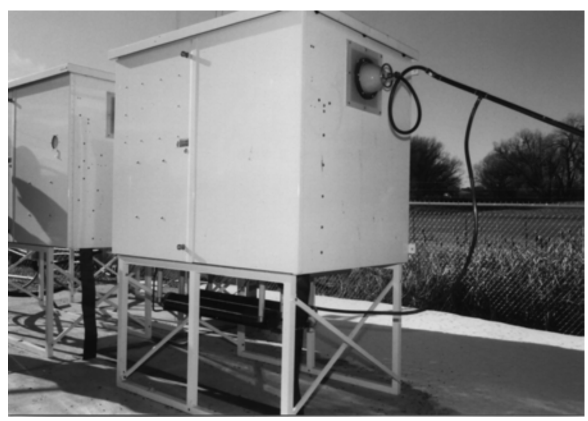

Figure 4

3.5 Diplexer Tune-Up

Diplexer tune-up is fairly straightforward. The series-resonant portion of each trap is set using a bridge for a net zero reactance on the pass frequency. The residual reactance of the series combination is measured using a bridge on the reject frequency. The reject resonating component is then adjusted for equal (but opposite) reactance. This procedure is repeated for both the main and auxiliary traps.

Once this “pre-tuning” is done, fine-tuning is done by feeding the reject frequency in at the diplex point with a signal generator and connecting an FIM tuned to the reject frequency at the transmission line input. Without touching the series networks, the main trap resonating component is then adjusted slightly for minimum reject frequency voltage as measured on the FIM. The signal generator and FIM are then tuned to the pass frequency and the aux trap resonating component is adjusted slightly for maximum pass frequency voltage. These traps should tune very sharply.

The pre-tuning and fine-tuning procedure must be repeated on the other side of the diplexer, minimizing reject and maximizing pass frequency voltage at the input.

Some pre-match networks consist of only a series component. Others have both series and shunt components. The pre-match, if used, should be set to the designer’s specified reactances.

Finally, with everything connected all the way through to the antenna, the input matching network for each frequency is adjusted to produce a 50-ohm non-reactive load at the transmission line input. The output J-plug shorting bar in the output of each other frequency’s filter cabinet should then be removed and the effect on the input impedance observed. Little or no change should be apparent. If a significant change is apparent, there is likely a problem in the main trap in the diplexer cabinet which was disconnected. Before any power is applied to the system, this must be investigated and corrected.

At this point, it is a good idea to measure the input impedance on the sideband frequencies (carrier ± 10 kHz) to see if the bandwidth is acceptable.

With the diplexer or multiplexer thus tuned, the transmitter for each frequency can be turned on and operation through the diplexer to the antenna checked. It is a good idea to bring up each transmitter by itself for a few minutes, observing transmitter operation, VSWR indication, modulation and base current. All excitation should then removed and all tuning and trap components checked for heating or evidence of arcing.

With everything checked on each side of the diplexer, both transmitters can be turned on and the entire system checked. After running all transmitters for a few moments with full modulation, it is a good idea to remove all excitation and again check all tuning and trap components for evidence of heating and arcing. Warm to the touch is okay; hot is not.

Some engineers like to further touch up diplexer tuning under actual operating condition. This is done by connecting an FIM tuned to the reject frequency to the modulation monitor output of each transmitter. While operating at reduced power, the trap resonating components are touched up for minimum reject frequency voltage as indicated on the FIM. This may produce another dB or so of improvement, but it is usually unnecessary.

The last step in a diplexer/multiplexer tune-up is to check occupied bandwidth and for intermodulation products. A spectrum analyzer and/or splatter monitor and FIM should be used for this. Measurements should be made at a clear location off-premises in accordance with the procedure outlined in the FCC rules.

4.0 Co-location of AM/FM - AM/TV

In the early days of FM and TV broadcasting, it was quite common to utilize an existing co-owned AM tower for the FM or TV antenna. This has become less and less common, as FM/TV installations typically require considerably greater height than most AM towers provide. Still, such installations are sometimes desirable and necessary.

The same principles used to co-locate an FM or TV antenna with an AM also apply to cellular, PCS and other wireless services as well, opening up an often much-needed revenue stream for the AM tower owner.

The challenge in utilizing an insulated AM tower for some other broadcast or wireless service is getting the transmission line across the insulated tower base without shorting the tower or significantly altering the base impedance at the AM frequency. There are several ways of doing this, all of which have advantages and disadvantages.

4.1 Isocoupler

The isocoupler is, from the AM engineer's point of view, the preferred means of coupling a transmission line onto an insulated tower. This device simply couples both the inner and outer conductors of the transmission line at the VHF/UHF frequency while keeping them decoupled at the AM frequency. Isocouplers come in different shapes and sizes, from small quart-size units for STL/RPU use to large, oil-drum size units for high-power FM/TV. Isocouplers operate over a specific range of frequencies and must be chosen for the specific application. In some cases, an off-the-shelf isocoupler will not work and something custom will have to be manufactured.

A well-designed and constructed isocoupler will present a very high shunt impedance at the AM frequency, changing the self-impedance of the AM tower very little or not at all. At the VHF/UHF frequency, however, isocouplers represent a significant loss, making them less desirable than other methods of coupling across a base insulator. They also tend to be a weak spot in the transmission line, subject to leaks (if pressurized) and damage from lightning.

4.1 Quarter-Wave Stub

Less desirable from the AM engineer's point of view but much preferred by the FM, TV or wireless engineer is the quarter-wave stub. The transmission line is installed on insulators all the way up the tower with a short to the tower installed at a point which is electrically a quarter-wavelength above the tower base. This acts like a quarter-wave transmission line, transforming the short at the quarter-wavelength point to an open at the tower base. In some cases, where the tower is less that 90 electrical degrees high for instance, it may be impossible to find a point to locate the shorting stub that will produce the desired high impedance at the tower base. In those cases, a resonating capacitor can be placed between the transmission line outer conductor and the tower itself and tuned for a high impedance.

This method can be a very economical means of coupling a transmission line across a base insulator, and it is certainly desirable from the FM/TV/wireless point of view because no additional loss is introduced. In addition, the expense of an isocoupler is avoided. That advantage is somewhat offset by the cost of the ceramic or porcelain insulators and the maintenance headaches that go along with them. These insulators and the resonating capacitor if used also tend to be something of a weak point, both mechanically and electrically, and are subject to failure and damage from lightning and the elements.

4.2 Isocoil

A third method that is sometimes used is the transmission line “isocoil.” The transmission line is wound onto a coil form and itself becomes a high-reactance inductor. A fixed capacitor is typically connected from a point on the coil to ground so that the L-C combination is parallel resonated to provide a high impedance across the tower base insulator.

This method is somewhat advantageous to the AM broadcaster in that it provides a low-impedance DC path to ground across the tower base, effectively bleeding off static electricity. On the other hand, the resonating capacitor can become a weak point, subject to lightning damage.

From the FM/TV/wireless standpoint, there is a practical limit to the size of transmission line that can be wound into an isocoil. Further, the line used in the coil will introduce a significant amount of loss.

Which method is chosen must be a compromise. It is impossible to couple across the base insulator of an AM tower without some penalty, on the AM frequency, the VHF/UHF frequency or both. The engineers’ job is to balance cost with risk and performance penalties on each side and come up with the best method for the particular situation. A competent and experienced consulting engineer can often draw upon years of experience with many such installations to help with the planning of the installation.

4.4 Folded Monopole

It is possible in some cases to take an insulated-base AM tower and make it a grounded-base tower, greatly simplifying the task of coupling an FM, TV or wireless transmission line onto the tower. This is done by installing a wire skirt onto the tower. A number of wires are installed on the tower legs, faces or both on fiberglass rods which hold the wires at a fixed spacing from the tower and insulate them. The ends of the wires are joined at the base and driven with the AM transmitter, and on the tower, the wires are joined at the quarter-wavelength point and shorted to the tower. Like the quarter-wave stub discussed above, this produces the same transformation as a quarter-wavelength transmission line, transforming the short up on the tower to an open at the tower base.

The advantage of shorting the tower base is that any number of transmission lines can be coupled onto the tower without isocouplers, insulators or isocoils. The disadvantage from the VHF/UHF perspective is that the skirt wires are often in the aperture of their antennas mounted on the tower, creating interference with their radiation patterns.

From the AM broadcaster's perspective, it has both advantages and disadvantages. The advantage is that the base insulator, which can be troublesome, is done away with. No static drain choke, ball gaps or lighting choke are needed. Because the shorting stub location can often be chosen to produce a driving point resistance of 50 ohms, the transmitter output can often be matched to the skirt with only a vacuum variable capacitor, doing away with several tuning components. However, since skirted towers usually have a Q of about 10, the driving point reactance can amount to hundreds of ohms. The reactance of the skirt in series with the capacitor needed to offset it produces a series tuned circuit that limits bandwidth. Changing environmental conditions, particularly ice on the skirt wires, tend to produce a shift in the driving point impedance. Another disadvantage is that the skirt wires and insulators add a considerable maintenance load.

A folded monopole can also be created using an existing FM, TV or wireless tower for the purpose of using the tower as an AM radiator. The challenge often becomes creating a ground system on an existing site with buildings, streets, driveways, parking lots and other obstructions present. In some cases, it may be possible to achieve acceptable results using an abbreviated or non-conventional ground system.

The other challenge that is often faced with skirting existing FM/TV or wireless towers is minimizing the effect of the skirt wires on the FM/TV or wireless antennas. With tall towers, this is not usually a problem as the skirt wires would extend only part way up the tower. With shorter towers, some compromise may have to be made.

5.0 Conclusion

With the high cost of real estate and the difficulty in obtaining regulatory approval for new tower sites, perhaps co-location at an existing tower site should be one of the first options examined rather than the last resort it has been in the past. Co-location can quite often provide an economical alternative to new site development, offering reduced construction costs and many times a more desirable location than a new rural antenna site. It also does away with the need for obtaining many of the regulatory approvals that would be necessary with a new site, such as FAA and zoning.

Careful planning, engineering, design and construction can yield a first-rate facility for far less money and in far shorter time than would be possible with new site development. In today's tower-unfriendly environment, it may be just the right fix for the site-challenged AM station.