A Preview of the FM Transmission Systems Course

Course Description

An FM transmission system, at its most basic level, consists of the transmitter, the transmission line and antenna. There are many variables within these basic building blocks, including types and sizes of antennas, size and type of transmission line, and transmitter power output. Situation-specific variables such as the allocation and class of station, permissible area to locate, permissible tower height, location of the tower site with respect to the target coverage area, and the local terrain all come into play in the proper selection of the correct tower, antenna, line and transmitter.

This course will provide the student with knowledge of all of the above-mentioned items and variables and how they impact the performance of an FM station. Upon completion, the student should have a clear understanding of the proper design, installation and maintenance of an FM transmission system.

Course Content

1. Antenna Site Considerations
2. Antenna Gain vs. TPO
3. Vertical Plane Characteristics
4. VSWR Bandwidth
5. Antenna Designs
6. Transmission Line Types
7. Transmission Line Selection
8. Transmission Line Installation
9. Maintenance

SBE Recertification Credit

The completion of a course through SBE University qualifies for 1 credit, identified under Category I of the Recertification Schedule for SBE Certifications.

Enrollment Information

SBE Member Price: $80

Non-Member Price: $115

Antenna Site Considerations

Antenna Site Considerations

While few of us have much control over the location of our antenna sites, perhaps there is room for change in some situations. For the rest, the information presented herein will help us evaluate the performance of our radio stations as a function of site location and antenna height.

Location, location, location. Those are the three most important factors in real estate, and they are equally important for radio transmission systems. This applies equally to AM, FM, TV, MMDS, wireless, two-way, paging, WiFi and other RF-based services.

Ideally, the antenna for an FM broadcast station would be situated at a location that would present a clear line-of-sight to the entirety of the desired service area. The antenna would have uniform horizontal- and vertical-plane radiation patterns, and there would be no reflections from natural or manmade objects.

Unfortunately, the real world is very different from this ideal. The real world is full of obstructions, manmade and natural, that partially or fully obstruct the path from the transmitting to receiving antenna. Real-world transmitting antennas exhibit some non-uniformity in the horizontal plane, and in the vertical plane, half of the energy is radiated above the horizon into space, where it is wasted. Reflections from objects also produce amplitude variations in the received signal that cause noise and signal dropouts.

The number of variables that go into the performance of a particular antenna site is quite large, and many of these factors are beyond the broadcaster's control. Many can be mitigated, however, with good site selection, and it is on those that we must focus when searching for an antenna site.

The goal of the broadcaster is to produce a signal of sufficient amplitude to overcome noise and provide at least 20 dB of signal-to-noise ratio at as many of the receiver locations within the desired service area as possible. How much signal is sufficient to meet this goal is largely dependent upon the receiver and its antenna. In the absence of interference, a signal level of as low as 2 uV/m may be sufficient for many of today's automobile receivers. Portables may require as much as 500 uV/m. Interference from co- and adjacent-channel stations usually increases the amount of signal required for acceptable reception.

Fresnel Zone

There is no substitute for a clear line of sight between the transmit and receive antennas. This is one of the first rules in VHF transmission. A transmitter site with a clear line of sight to virtually all the target service area is thus superior in most cases to one that is blocked by terrain or manmade obstructions to parts of the area. In some cases, simply having line of sight is not enough. In engineering our microwave and UHF STL paths, we always consider Fresnel zone clearance, knowing that a path with less than 60% first Fresnel zone clearance will be marginal. We often neglect this consideration in engineering our FM transmitting antenna locations.

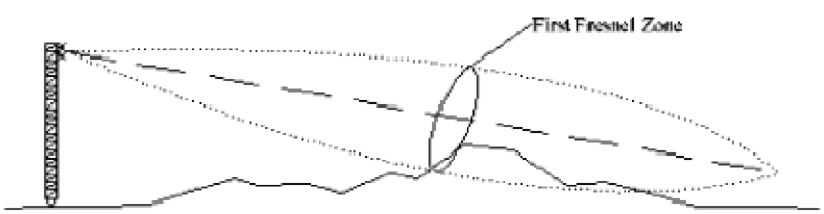

Figure 1 - Fresnel Zone

For those not familiar with Fresnel zone clearances, they are circular areas surrounding the direct line-of-sight path that vary with frequency and path length. The longer the path and lower the frequency, the larger the mid-path clearance required for clear-path reception. As mentioned above, 60% first Fresnel zone clearance is all that is required to meet the clear-path reception objective, but that can be quite large at FM frequencies. The first Fresnel zone radius can be computed using the formula R = 1140 /d/f, where R is the radius in feet, d is the path length in miles and f is the frequency in MHz.

A quick example of 60% first Fresnel zone radius for a few typical broadcast situations are 267 feet for a class A, 378 feet for a class B and 463 feet for a class C1. Keep in mind that we're talking about terrain clearance at the mid-point between the transmitting and receiving antennas required to produce clear-path reception. These translate to antenna heights above ground of 534 feet, 756 feet and 925 feet respectively. With the exception of the class C, the antenna heights are well above the maximum height above average terrain (HAAT) values for the classes.

Figure 1 above shows a clear line-of-sight path, but terrain intrudes into the first Fresnel zone. This represents a compromised path with considerable attenuation, the line-of-sight path notwithstanding.

This brings us to the conclusion that height is a very significant factor in most antenna site situations. As a rule, greater height is more useful than higher power in producing higher receive signal strength, all other factors being equal.

Multipath Considerations

Multipath is a nasty word in the vocabulary of most radio engineers and station managers. It is a good descriptor of the destructive effect of the same radio signal arriving at a receive point by multiple paths. When these signals arrive in phase, all is well and the incident field strength is greater than it would be in the case of a single signal path. When they arrive out of phase, however, at least some degree of cancellation will take place, resulting in a reduced incident field strength, with complete cancellation (zero incident signal) taking place in the worst case situations.

To make matters worse, sometimes, complete cancellation can take place on frequencies close to carrier while less than complete cancellation takes place on sideband frequencies. This in many case results in a demodulated sound much more offensive to the listener than the quiet hiss of no signal. Motion in an automobile produces a constantly varying multipath situation, often causing picket-fencing (the effect of the slats in a picket fence alternately permitting and then blocking the signal), which is quite objectionable to the listener.

The worst-case multipath scenario is where the transmitting site is located on one side of the service area and a range of mountains or high hills is located on the other. Receivers within the service area get the direct line-of-sight signal from the transmitting antenna, but they also get a reflected signal from the mountains or hills. In such a case, there will be few locations within the service area where multipath effects will not be a factor.

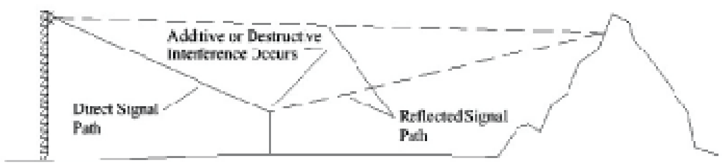

Figure 2 - Multipath

Perhaps the best location for a transmitting antenna in such a geographic scenario, assuming that a mountaintop location is out of the question, is on a hill near the mountain range. A directional antenna would then be used to reduce radiation toward the mountains and maximize it toward the service area. This will result in greatly reduced reflections. While it would be impossible to completely eliminate reflections, they could be reduced so that the ratio of direct-to-reflected signal at most locations throughout the service area is sufficiently high to nullify the effects of multipath.

Grazing Angle

Ground reflections play a part in the overall propagation of FM signals, particularly the vertically-polarized component. Almost all FM signal coverage lies between the horizon and 10 degrees below the horizon. This is called the *grazing angle*, and it lies between the horizontal plane from the transmitting antenna and the earth's surface. Vertically-polarized energy is attenuated considerably more than horizontally-polarized energy at angles greater than about 2 degrees, with a peak attenuation occurring at about 11 degrees (the *Brewster angle*). As a result, circularly-polarized signals tend to be reflected more as elliptical rather than circular. It is important in site selection to avoid grazing angles to the desired service area which are greater than about 2 degrees. Simple geometry would suggest that sites close in to the service area would be more prone to produce such high grazing angles, indicating that a more distant site may be preferable.

Vertical Radiation Pattern

We mentioned early on the vertical-plane radiation characteristics of real-world transmitting antennas. Some of these characteristics come into play when selecting a transmitting antenna site.

The more bays an antenna has, the narrower the main elevation plane will be.

If a transmitting antenna is located at a considerable height above the target service area, the main elevation plane lobe may overshoot the target service area, with the energy being radiated out into space. The more bays an antenna has, the narrower the main elevation plane will be. Antennas with a small number of bays (less than four) exhibit a broad elevation plane lobe, making such overshoot of the target service area less likely.

Figures 3 and 4 show the vertical plane patterns of six- and four-bay antennas, respectively. Note the deep vertical plane first null at -10 degrees for the six-bay antenna. If the antenna height is 500 feet, that null will occur at about 2,800 feet from the tower base, just over half a mile. A signal null will thus occur in a band around that tower at that radius, impacting any population in that zone. The two-bay's first null occurs at 30 degrees below the horizon or thereabouts. For a 500 foot antenna height, that null will fall at about 850 feet from the tower, making it much less likely to impact population.

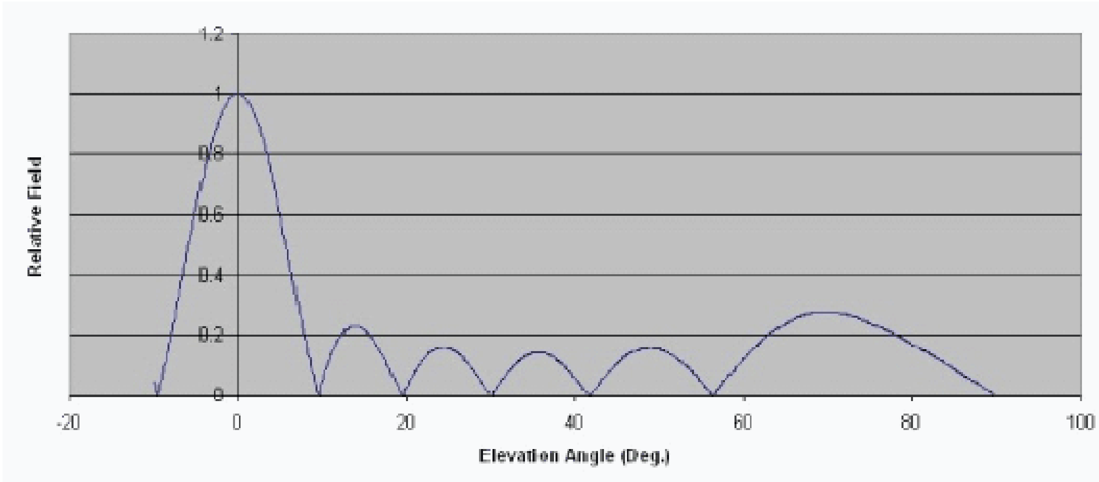

Figure 3 – Vertical Plane Pattern of a Six-Bay Antenna (full-wave spacing)

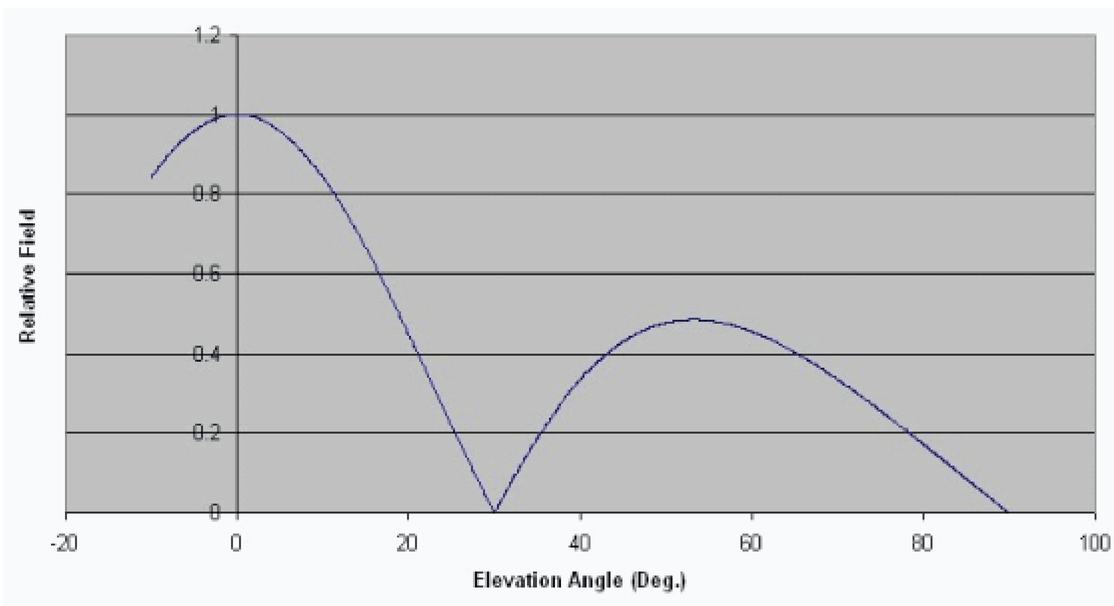

Figure 4 – Vertical Plane Pattern of a Two-Bay Antenna (full-wave spacing)

In those situations where a large number of bays is used and the antenna is high above the target service area, it may be desirable to employ ***beam tilt*** to lower the beam angle slightly. Typically, just enough beam tilt is used to center the main elevation plane lobe on the distant edge of the target service area or on the horizon, whichever is closer. We will discuss beam tilt in more detail in Section 3.1 below, but it is mentioned here because it does impact site selection.

Antennas with a large number of bays exhibit elevation plane nulls. The more bays an antenna has, the farther away from the antenna site that these elevation plane nulls hit the ground. If the area within a few miles of the antenna site is populated and it is desirable to provide service to this area, it may be desirable to employ ***null fill***. A very small amount of null fill is all that is necessary to provide adequate service in these close-in areas. We will discuss null fill later in this course.

Which class of FM station can most easily obtain sufficient antenna height for the desired Fresnel zone clearance?

- Class A

- Class B

- Class C
- Class D

Multipath interference is caused by:

- Distant stations on the same frequency as your transmitter.
- Distant stations on the first and second adjacent frequencies.
- Nearby stations that are 10.6 or 10.8 MHz from your carrier frequency.
- The reflection of your own station's transmitted signal.