LOW-POWER BROADCASTING

Low-power broadcasting systems are very interesting from a technical perspective for several reasons. Although they appear to be simple to build and easy to design, they can actually be more critical than higher-powered stations. In fact, since the signal is local and likely to receive or cause interference, design and optimization methods for low-power systems can make the difference between a successful operation and a failure.

It is a mistake to think that a low-powered facility cannot perform as well (within its intended coverage area) as a full-powered station. Around the world, there are many facilities operating at low power that provide excellent full-time service to communities every day.

Modern techniques allow some very interesting project work, such as synchronized systems, directional systems to fill in specific areas, and local systems (such as in tunnels, buildings, or temporary high-density populated areas such as stadiums). These techniques also have application for fill-in service for satellite-delivered services as well as terrestrial digital broadcasting.

DEFINITIONS

A low-power station is typically a facility with a transmitter power of 1 kW output or less. Although antenna gain plays a large role in the effective radiated power (ERP) of a given facility, it is easier to define the power of a station in general terms by transmitter power. However, when regulating the location and coverage of a given facility, ERP and height above average terrain (HAAT) are often specified.

Translator

A translator is a radio frequency (RF) device that retransmits a television or FM signal within a specific broadcast band. The translator alters none of the signal characteristics except frequency and amplitude with a main purpose to extend or fill in the coverage of a transmitted signal. It typically receives a signal, changes its carrier frequency, and then rebroadcasts the changed carrier at substantially higher levels of radiated energy. A translator is essentially a repeater.

As an example, a broadcast station might have a zone within its trade area that receives a poor signal from its main transmitter. The technical consultant of the station prepares a study to identify the existence of frequencies for a translator. The consultant recommends a site and a specific design.

Listeners and/or viewers within the coverage area of the translator receive primary station programming on a different frequency from the primary station. Thus, the station signal is translated in that area.

J. Webster (ed.), *Wiley Encyclopedia of Electrical and Electronics Engineering*.

Booster

A booster is an RF device that retransmits a TV or FM signal within a specific broadcast band. It alters none of its characteristics, including frequency or amplitude, with a main purpose to extend or fill in the coverage of a transmitted signal. A booster operates on the same frequency as the primary signal and rebroadcasts it at substantially higher levels of radiated energy. The signal of a booster is the same as the primary station. Boosters are complicated, and a poorly designed or built booster can cause much more harm than good. A booster is an isofrequency transmitter.

As an example, a station might have a location within its trade area that receives a poor signal from its main transmitter. The consultant of the station prepares a study to identify a site with appropriate terrain shielding or to allow the operation of a booster without substantial interference to or from the main signal. Listeners and/or viewers receive the programming from the primary station on the same frequency as the primary station. Thus, the station signal is boosted in that area.

LPTV

An LPTV (low-power television) station can be defined as one that may operate as a translator or originate programming and operate as a subscription service low-powered TV system intended to serve a local area. It functions as a full-powered TV station, but with reduced output power.

ITFS, MDS, and MMDS

ITFS (instructional television fixed service), MDS (multipoint distribution service), and MMDS (multichannel MDS) are television transmission systems authorized to provide specific programming to subscribers. Technically, ITFS and MDS are quite similar to each other as well as to broadcast television transmission.

GENERAL GUIDELINES

Following are some tips and points to consider when designing a low-power system. Some of these items are simple common sense; others require high-powered computer system analysis to compare options and identify predicted results. These guidelines also apply to high-powered systems. In most cases, low-powered systems have very stringent requirements due to specific signal challenges. Before designing a system, a complete understanding of all the technical issues will minimize problems. The field is quite complex. For example, propagation and signal analysis is a career unto itself, but understanding the basics will help you identify potential problems in the initial design of a system. Use the services of a professional who designs systems regularly for the best results.

Location of Antenna in Relation to Population

Locate the transmitting antenna site as close to the target population as possible. Building penetration and received signal strength decreases rapidly as distance between transmitter and receiver increases. RF energy diminishes with the square of the distance. If the transmitter site is distant from the target population, system design is much more critical and difficult.

Height of Antenna Above Population

More antenna height usually means better coverage. However, one should specify an antenna height as high as is needed for the specific requirements, but not any higher. Excessive antenna height leads to unnecessary interference, increased cost of construction and operation, and decreased reliability. The antenna should be just high enough for adequate Fresnel ellipsoid clearance to the target area but not much above that height.

Fresnel Ellipsoid Clearance of Signal into Target Market

The antenna signal is not a narrow ray of energy like a laser beam. The signal is a noncoherent three-dimensional beam that gets wider as it leaves the transmitting antenna, just like the beam from a flashlight. For maximum received signal strength, all the energy in the Fresnel ellipsoid must pass from the transmitter to the receiver with no obstacles affecting the path of transmission. The receiving antenna works exactly opposite from the transmitting antenna. It gathers energy from a three-dimensional area and narrows it down to the location of the receiver, just like a telescope gathers light from a wide area and focuses it at on small area. At the midpoint of the transmission/reception path, the signal beam is its widest. Therefore, even if you can see the population you want to serve from the transmitter site, the broadcast signal may not be able to reach it due to obstructions below the line of sight path.

Tuning and Installing an Antenna

A transmitting antenna is just as sensitive to its immediate environment as a receiving antenna. If you have ever adjusted a “rabbit ear” antenna on a TV set or the rod antenna on a “boombox,” you understand the concept. A very small change in the antenna orientation or environment has a drastic effect on its performance. Install the antenna and tune it properly from the beginning and the facility will perform as predicted. The supporting structure, the antenna design, and the way the antenna is mounted all affect the quality of the signal.

Elevation Pattern of an Antenna

There is often population below the height of a transmitting antenna—especially if it is on a tall tower or hill. The elevation pattern of the antenna identifies the amount of signal radiated toward the horizon as well as the amount radiated below the horizon, into low-lying population. The elevation pattern is critical in systems design because control of energy in specific areas can be an important factor in system performance. Conversely, a receiving antenna often receives from a location above its horizontal plane, and the elevation pattern above the horizon is important. The number, spacing, and type of elements in the antenna array typically control the elevation pattern of a wire-type antenna.

Interference from Adjacent and Co-Channel Stations

Unless the station is located in an area with very few signals, certain portions of the service area will receive interference from other nearby or more powerful transmitters. This can come from stations as far as three channels above or below the carrier frequency. Consider the potential of interference in the design of a facility. Most complaints of poor performance are a result of interference, due to poor signal from the intended transmitter in an area or excessive signal from an interferor or "jammer."

Receiver-Induced Third-Order Harmonic Interference

When a receiver is near other transmitters, even if the desired station has a strong local signal, the receiver will overload or "be blanketed" by the relatively higher signal levels of the jamming transmitter. The selectivity (ability to reject strong local interference) of the receiver determines its susceptibility to this kind of interference. In other cases, harmonic mixes occur within the receiver itself, causing the desired signal to be jammed. This situation is receiver-induced third-order harmonic interference.

Condition of Antenna System

Most transmitters have a test meter that indicates if the antenna has failed to the point that it can harm the transmitter. However, there is typically no accurate test equipment available at a transmission facility to show qualitatively how well the transmitter or antenna is performing. Most antenna complaints are very subjective: You just cannot "get" the station as you used to; it does not sound right or look right any more, and so on. The only way to tell if an antenna is working correctly is to test it with appropriate test equipment used by antenna manufacturers and consultants.

Quality of Modulation

A commonly overlooked cause of signal problems is poor source material. In this case, no amount of improvement to the antenna or transmission system will correct the problem.

LOW-POWER SYSTEM DESIGN

Site selection is the first step in designing a system. The details of the site determine many other design criteria, so an overall review of the impact of any potential site must be exhaustive. Choice of the best site for a transmission system is often a series of compromises. Strike a balance between economical issues, environmental issues, and performance issues of the particular site under review.

In addition to these restrictions, the site must be available; must satisfy all regulatory, practical, and engineering requirements; and must be accessible during the time construction is planned to take place.

The primary technical consideration of site selection is the performance of a transmission system that is located there. Computer analysis should be performed to predict the performance at all intended receiving locations, to predict the interference generated to other operators from the proposed site, and to demonstrate the relative quality of any particular site with others being considered. In addition to the performance of the transmitter(s) located at the proposed site, receiving capability of the primary signal must be possible. This may mean satellite reception, microwave link reception, or off-air reception of the modulating signal.

When using off-air rebroadcast, the site selection is critical. For example, if a booster receives its primary signal from a receiver tuned to the primary FM transmitter, the booster's transmitted signal generally ranges from 90 dB to 110 dB stronger than the intended input signal. If feedback contamination is to be limited to less than 30 dB, the transmitting antennas and receiving antennas have to have between 120 dB and 140 dB isolation.

A high degree of shielding between the antennas is required. Sometimes this can be accomplished by terrain or even by a building. Depending on system power levels, a physical separation between highly directional antennas may be enough.

It is good engineering practice to choose a site that is accessible in varying weather conditions. That is, it cannot be subject to factors such as excessive winds, erosion, snow, heat, or water.

Antennas

Some system designers mistakenly believe that running all the power the license permits and using the largest antenna they get is the best course of action. The problem with higher-gain antennas is that they have small vertical beamwidths that can cause dead spots in the minor lobes due to the nulls in the radiation pattern. Since the major lobe provides the most gain to the detriment of areas near the antenna, signals in the remote areas will likely be excellent, at the cost of local signals. Sometimes, however, this is an intended effect when areas near the antenna are lightly populated.

Beamtilt will not solve a problem caused by insufficient Fresnel ellipsoid clearance ("shadowing"). Antenna tuning will also not solve this kind of problem. If a site has poor performance due to radio shadowing, no amount of manipulation of the antenna system will make a substantial improvement over a properly operating antenna system. Some operators are willing to pay for minor improvements, but a better use of finances is to analyze carefully a potential site before building it. Examine every proposed system with care to analyze accurately the magnitude of the potential problem areas. Antenna pattern control equals better system performance, less co-channel and adjacent channel interference, and better spectrum utilization.

Transmitting Antennas. There are a number of factors to consider when it comes to designing the antenna system for a low-power operation. Careful attention to materials selected is key. A poor-quality antenna will adversely affect the best system. For omnidirectional usage, use low-power versions of the standard higher-powered transmitting antennas. (They are available in horizontal, vertical, and elliptically polarized models.) Virtually all transmitting and receiving antennas are available in 50 Ω or 75 Ω models. The relationship between the tower and the radiating elements is essential. The best designs are custom tuned for the specific situation.

When designing an antenna system, make sure that antenna and tower manufacturers or owners are kept abreast of any possible problem areas, such as wind resistance, the antenna's postinstallation directivity patterns, and mounting procedures.

Calculate ERP by multiplying the antenna's power gain by the transmitter output in watts less losses (hybrid, coax, duplexer, circulators, etc.). Be aware of the antenna's vertical plane pattern as well as the probable signal levels at various points in the service area, because the measuring gain on VHF antennas is usually set at zero degrees. (The gain at other elevation angles may be considerably less.)

Antenna beam width equals the number of degrees between the major lobe half-power points. If it is necessary to have coverage in local *and* distant areas, choose the highest possible antenna location and the antenna configuration that will be the best compromise. A high antenna with no obstructions between the transmission site and the receiving sites is required for consistent service to the intended audience.

If local coverage is of paramount importance, utilize a high-gain antenna with a moderate degree of beamtilt, or lower power and an omnidirectional antenna. This will make the best use of radiated power and reduce interference.

Receiving Antennas for Retransmission. The input signal's delivery to the transmitter is an essential factor in overall system design when retransmitting a signal. A poor-quality input signal makes all the difference in the entire operation of the system.

A simple antenna on a nearby tower is sometimes sufficient for off-air reception. More often, measures that are more intricate are necessary. Sometimes increasing antenna gain or narrowing the pattern of the arrangement is an option. A 30° horizontal pattern width from a single receiving antenna has been known to allow for reception of an interfering signal. A number of methods can resolve retransmission reception difficulties, including signal filtering to minimize out-of-band products, antenna-mounted preamplification to increase signal levels, and horizontal and vertical antenna stacking techniques to increase antenna gain and directivity.

The majority of difficulties related to the input signal have to do with weak input signal strength, measured in microvolts on the receiver front panel. Depending on the manufacturer, equipment specifications usually specify that 2 μV to 10 μV will result in a good output signal, but those numbers are reflective of equipment capabilities only.

Practical limits at a site tend to be much higher for several reasons. Depending on local conditions, weak signals can result in fades. Upward of 100 μV to 300 μV is usual, but even this level of signal can have problems during a fade. Carefully monitoring proposed sites helps avoid the problem from the start. The level of RF noise near a receiving antenna can influence input. Noise levels can be higher than the signal strength of the desired signal. Subsequent filtering or antenna location can help resolve the issue.

In many cases, one must take special measures to ensure that reception and retransmission signals stay clean. A weak signal with poor signal-to-noise ratio is generally the problem. The system's receiving section must contain a superior signal conditioning system, preamp, and receiving antenna to maximize clarity.

ANTENNA STACKING

Antenna stacking increases the gain of an antenna array. Stacking can be either horizontal or vertical. Stacking applies in transmission and reception and can be helpful in solving certain reception difficulties.

Vertical antenna stacking influences vertical beam width. It is effective in amplifying the gain of the array. Horizontal stacking narrows the array's beam width from side to side. If the antennas are in phase, this method adds 3 dB to antenna gain for every doubling of the stack. (A single yagi antenna has a horizontal acceptance angle of approximately 30° between the 3 dB down points off its front.) Note that horizontal beam width decreases considerably and vertical beam width remains unaffected.

A variation in stacking resolves certain interference and reception difficulties. There is a myriad of ways to make use of this technique, including offset antenna arrangements, which allow phase reinforcement off the front of the array and phase cancellation off its rear. The process involves vertical stacking of the antennas (that is, one antenna forward of another by precisely one-fourth lambda at the center frequency of the rejected channel). Use this formula to calculate stacking:

$$D\,(\text{in.}) = \text{2951 divided by the frequency of the undesired signal in megahertz}$$

RF signals travel faster in free space than in cable, so connect the rear antenna to the common junction with a short feedline. Then connect the front antenna to the common junction with a feedline whose length results from the formula multiplied by the velocity of propagation of the cable used, plus the amount of cable that is used for the rearmost antenna.

As another example, set the space from one antenna boom to another so that it will cancel an unwanted signal from a specific forward direction. Install the antennas with the center of each spaced so the unwanted signal is out of phase at the connection between the two antennas, and the interfering signals will negate each other at the combined output.

Transmitters

Transmitters provide the RF power for the antenna. Proper design of a low-power facility includes selection of the appropriate transmitter for the job. A primary consideration is adequate power in order to achieve desired effective radiated power. The gain of the antenna(s) and the length of the transmission line(s) affect this power level requirement. The available electrical power and the cooling system available at the transmission site also affect the RF power level design. Generally, low-power facilities do not need more complex electrical power systems, such as three-phase power or high-voltage power systems. As in any design, the transmitter should be well designed and easy to maintain and provide diagnostic information about its status and condition.

ITFS and MDS Transmitters. Usually, transmitters for MDS and ITFS rate at 10 W to 100 W visual power and 10% aural capability. 10 W transmitters are typically solid state. Higher-powered transmitters typically operate with vacuum tubes.

Internally and externally diplexed transmitters are widely used. Low-level internal systems work well in uncongested areas due to their ease of use and cost efficiency. Externally diplexed systems reduce cross modulation of video synchronization components onto the aural carrier. They also offer better rejection of products caused by the intermodulation of aural and visual carriers. Aural carrier signal integrity is a considerable element in system performance with multichannel sound and pay television encoding and decoding. Amplitude, phase precorrection methods, and contemporary linear amplifier design ensure good signal performance.

LPTV Transmitters. When choosing an LPTV transmitter, there are a few terms to remember. Linear waveform distortion, called the "$2T$ K factor," measures the distortion of a picture's fine detail. The $2T$ sine-squared pulse and the $2T$ bar define the K factor, or actual distortion. The K factor must be less than 3% to meet LPTV standards.

Envelope delay is the delay within the system of the modulation envelope. It is usually a frequency function, with higher frequencies equaling shorter delays. For transmitters, the standard is built on a baseline of the delay within the equipment between 0.05 MHz and 0.2 MHz. For up to 3 MHz, that delay is to be maintained. Past that, the delay should linearly decrease up to 4.18 so the delay is -170 ns with respect to the baseline at 3.58 MHz.

Differential gain is the difference in gain of the LPTV system's translator for a small, high-frequency signal (chrominance) at two specific levels of a low-frequency signal (luminance) upon which the high-frequency signal is superimposed. Differential gain cannot exceed 10% at an average picture level ranging from 10 to 90%.

Differential phase is the difference in the output phase of a signal such as that used in differential gain measurements. It should never exceed 7° past the range of blanking to white.

FM Transmitters. Low-power FM transmitters are usually either a standard FM exciter with low-pass filter or an exciter with a low-power amplifier. Many of the low-power systems are solid state; others operate with vacuum tubes. In a translator or rebroadcast application, several systems are available as complete solutions, with built-in receivers and audio processors. In most cases, the transmitter is simple to install and operate.

Transmission Lines

Transmission lines play a major role in the design of a low-power system. They provide the connection between the antennas and the equipment—whether transmitters or receivers. It is common for designers to pay little attention to this important part of the design process. In fact, often, low-power systems designers completely forget about the existence of feedline losses. Since these installations operate at low power and are usually on a tight budget, they generally use inexpensive small-diameter coaxial cables. The savings in transmission line costs tend to result in a compromised signal level.

Detailed engineering data are available to allow the user to calculate accurately and compensate for feedline losses. Use the best cable in low-power applications to maximize the power delivered from the transmitter to the antenna or from the antenna to the receiver. The antenna can only radiate the power it receives.

Avoid using a foam-type dielectric cable unless it has a rigid outer connector. Foam dielectric is flexible and has no need for pressurization, but extended exposure to high temperatures can result in migration of center conductors and impedance variations. In some cases, rigid outer conductor foam dielectric cable may be more cost efficient than air dielectric lines if it is installed carefully without sharp bends or kinks. Keep in mind that air dielectric cable, or some alternate means of delivering nitrogen gas, must be provided if the antenna requires pressurization.

An air dielectric transmission line has a spiral-wound spacer that runs along its length to hold the center conductor in place. It is harder to handle and install than foam because it is so stiff, but it is much sturdier. Air dielectric lines have diameters ranging from $\frac{1}{2}$ in. to 5 in., but the most common sizes for low-power operations are $\frac{7}{8}$ in. and $1\frac{5}{8}$ in.

Here are some important points to remember about coaxial cabling:

The coaxial cable and connector quality is just as important as that of the quality of the system components. All it takes is one bad connector to make a system worthless.

Use a semirigid line for optimum performance. Never use braided cables. If there is any cross coupling between receiver cables and transmitter cables, all the isolation available will be unusable. Since shield movement can cause noise in systems, secure all flexible cables to keep them safe from strain and unnecessary motion.

Become familiar with the dielectric material, as connectors are the weakest link in every coaxial cable system. Avoid nylon connectors—they can soak up moisture as well as high-frequency RF energy. Polystyrene and Teflon are excellent choices. Only buy superior-quality connectors from a company with a respected name.

Avoid permanently installed adapters. Adapter construction is a compromise providing greater loss and inferior stability than using the correct cable terminations. It can introduce high VSWR into the system, thereby deteriorating overall performance and decreasing isolation.

Above all, pay attention to manufacturer instructions. Just about any good-quality connector works well if protected from cable motion and properly installed.

Towers

The supporting structure for a low-power antenna may be very short, or it can be 500 m tall. Tower design details are beyond the scope of this article, but it is important for the designer of a low-power system to be aware of various aspects of tower use.

Towers are expensive and dangerous and have a tremendous impact on the surrounding environment. Delays in construction can last for years if proper planning and coordination does not occur. In the initial design phase, use of only the best-quality tower can help avoid many devastating problems in the end.

The loss of a tower can cause more time off the air than the loss of any other major component and can cause severe damage as well. It is essential to give proper attention to the tower supporting any broadcast antenna. While purchasing the best tower money can buy sounds like an expensive proposition, it is nothing compared to the cost of two towers plus any damage resulting from failure.

Frequency Separation

The strategy of frequency or channel selection for low-power systems, particularly translators, is an art form of itself. According to a common theory, the output frequency of a translator should be as close to the input as possible and ideally an adjacent channel. The reality is that practical and technical issues may preclude this possibility. The majority of quality equipment should be able to operate well on adjacent channels, but there are other more complex issues. For example, operation of a translator on an adjacent frequency always causes interference to the main station. If the translator is located in the center of a large population, it could actually cause more harm than good.

On the other side of the coin, there is no limit to the frequency separation. Somewhere between the two extremes lies the solution. If maximum quality is the design goal, use at least 2 MHz separation for an FM translator and 60 MHz for a TV translator so that filters and traditional engineering solutions can be used in case of installation difficulties.

Signal Treatments

If every installation were perfect, there would be no need for signal treatment. The only time it is unlikely that special treatment for reception or transmission of a signal will be needed is when the facility is located away from all other transmission and reception systems and is not near a populated area. In most of the real world, planning for signal treatment is necessary and important in system design.

Receiving Preamplifiers. Many manufacturers produce tower-mounted preamps with gains ranging from 10 dB to more than 60 dB. Since the received signal may experience increased noise and loss as it travels from the cable to the translator, mount the preamp as close to the antenna as possible. A high-quality amplifier should have no effect on signal reception except to increase amplitude to conquer cable and/or system losses as well as render the signal useful. A preamp with greater gain does not necessarily mean better performance than one with a smaller gain. The reason is that high-gain preamps become more subject to overload as signal input increases. Select a preamp so that installation and input signal requirements are compatible. Overloading during input will result in distortion that can never be "cleaned up" afterward. Moreover, if a preamp experiences a poor signal-to-noise ratio at the input, an equal or slightly worse signal-to-noise ratio will be on the output.

Receiver Filtering. There are many ways to implement filtering. When a low-power receiver is tuned to a frequency near its output, increased out-of-band products result. In early gain stages of receiving equipment, tuning is broader, and a strong first or adjacent second signal may overload the input or mix in the receiver. Increased sharpness of input tuning can result in an increase in system noise.

Traps or bandpass filters at the input or at the tower may help in certain situations. Usually, a bandpass filter attenuates everything but the desired signal and a trap may attenuate a specific signal, causing interference.

Transmitter Filtering. Bandpass cavities are commonly used to reduce a transmitter's side-band noise. They pass the desired signal with a minimum of loss while sharply attenuating those frequencies that lie above and below the passband.

Notch cavities have a response curve that is the reverse of a bandpass filter—it possesses the same general configuration. Some people call a notch cavity a trap filter or a reject due to its ability to pass the desired frequency while it suppresses the rest.

Pass reject (sometimes called "pass notch") cavities are a combination of the two other cavities. When the interfering frequency is extremely close to the undesired frequency, a pass reject is used.

Combiners. Wireless communications usage increases every day, and tower or system space is becoming more difficult to arrange due to environmental pressures, lack of real estate, and costs. Transmission sites are becoming crowded, and these trends are resulting in a greater need to mix two or more transmitters into one antenna. Combiners do a number of good things at the same time. They filter potential interference and intermodulation, they provide isolation between transmitters, and they allow two or more transmitters to be mixed into one coax run and antenna. Although combiners themselves are relatively expensive, the cost savings to operators of tower sites are high.

Cavity combiners are generally manufactured from intercabled bandpass cavities. The isolation is the result of the cavity's resonant response curve. Sometimes pass reject cavities provide for closer frequency spacing or better isolation.

Advantages of cavity combiners include flexible configuration, cost efficiency, and low insertion loss. Negative features include large size, reduced channel capacity, and possible redesign of a combiner when frequencies are changed or added.

Use a combiner when the frequency spacing between channels is extremely wide. The minimum spacing for the FM band is usually about 1 MHz.

INSTALLATION AND TROUBLESHOOTING

Every transmitter site has a potential for problems. While it is impossible to anticipate every conceivable difficulty, proper foresight and planning can help avoid the likelihood of many disasters.

Boosters

Boosters may experience two kinds of major problems. The first problem is when the booster's output corrupts the input with the booster's signal. The second example occurs at a location that receives signals from the booster and the original station.

When isolation between receive and transmit antennas is less than the booster's overall gain, the result is a power oscillator rather than a power amplifier. Log periodic antennas rather than omnidirectional antennas are highly recommended. Self-oscillation takes place when the booster is transmitting an unmodulated signal and the booster's power meter indicates normal operation. Try turning the RF gain control down. If the transmitted signal sounds clean, advance the gain control until the system breaks into oscillation and find a compromise gain setting.

If that does not solve the problem, then the installation is to blame. Disconnect the receive antenna from the down converter. If the oscillation persists after the antenna is disconnected, there are a few things to do:

The transmission line is carrying energy to the down converter. Burying the interconnecting transmission line underground often resolves the situation.

If there is no energy present at the down converter end of the transmission line, relocate the transmitting or receiving antennas or both. Or shield the receiving antenna by locating it over the edge of a hill or behind an obstruction such as a water tower. One more solution is to increase the separation between the transmit and receive antennas until the system is stable.

Translators

If an installed translator fails to operate correctly from the beginning, the cause is nearly always site related. Problems can generally be traced to at least one of the following:

Receive and Transmit Antennas Are Too Close. Translator output power is usually in the millions of microvolts while the input signal is just a few microvolts. Poor translator performance is the result of spacing the antennas a few meters apart because the relatively high-powered output puts too much strain on the receive section. A distance of at least 15 vertical meters is recommended. To ascertain whether antenna separation is the problem, replace the transmit antenna with a dummy load.

Incoming Signal Is Poor Quality. Translators cannot improve the quality of signal they receive. Some translators are operational with signals from primary stations as much as 160 km away, usually when the elevation is high at the transmit and receive points and low at the transmission path. It is important to monitor the received signal for a good length of time using recording equipment in such cases, since signal quality can come and go.

An Adjacent Channel Is Present. This can be exasperating, because the adjacent channel can sound weak and yet be powerful enough to create distortion in the desired signal. When modulation components overlap on adjacent channels, mixing occurs, resulting in deceptive product generation. The problem can be fixed through special intermediate filters or external filters on the receive antenna.

A High-Powered Station Is Nearby. Serious performance issues can arise when the FM station's output energy mixes with that of the translator. This is a common problem. Tubes and output transistors are not totally linear and thus tend to operate as mixers, producing false signal generation that interferes with sensitive receiving equipment. Because the problem goes away when the translator is shut off, inexperienced technicians tend to blame the translator. The truth is that all translators react this way under the same conditions. The goal is to keep external signals from the final RF stage of the translator. Installing an isolator in the output transmission line is a cost-efficient way to solve the problem. A second option is to employ a high Q cavity in the output, which bypasses the translator output and rejects the offending signal.

Input and Output Channels Are Too Close in Frequency. The majority of transmitting equipment (including FM translators) produces spurious emissions extending several megahertz from the principal carrier. These signals possess an infinite amount of signals with the same frequencies as the desired signal so they infiltrate the translator and are amplified. Solve the problem with good antenna and frequency separation, usually with at least 1 MHz between input and output.

Harmonic Problems Cause Interference. The translator's main carrier is almost always the cause. It overburdens the front of the translator or the preamp associated with it. Although the translator suppresses harmonics by at least 60 dB, the seemingly obvious addition of an extra external harmonic filter will not do a bit of good. By placing a bandpass filter into the translator in front of any preamplification, the interfering signal will be too feeble to cause difficulties. Alternatively, try moving the translator installation far enough away that its carrier will not be powerful enough to do harm.

ITFS and MDS

There are a number of potential RF system difficulties with IFTS and MDS. Both services use 100 W or less per channel, so field intensities are fairly low in contrast to full-service broadcast. The ITFS and MDS services rely heavily on radio line-of-sight coverage, so the use of frequencies greater than 2000 MHz creates a need for better consideration of signal path clearances. The receive system needs a low noise figure down converter (which generally changes a block of the ITFS/MDS band frequency to VHF) and a relatively high-gain antenna. Other problem areas include adjacent and co-channel interference. As the spectrum becomes more crowded, the probability of interference grows in relation. In response, many cities are planning adjacent channel systems. A number of MDS systems, in particular, are already experiencing co-channel interference troubles. As the ITFS band grows, so does the likelihood that it, too, will develop problems.

Luckily, a good number of the common engineering principles that solve UHF and VHF broadcast difficulties are proving helpful. Suppressing out-of-band products is essential, as older transmit systems frequently display high levels of lower sideband reinsertion and out-of-band product formation. Externally diplexed linear transmitters and waveguide filters can bring these products to more workable levels. Offset frequency operation can be utilized with relatively high levels of co-channel interference.

The area of best signal coverage is within the areas receiving the entire Fresnel ellipsoid. These areas can extend beyond visible line of sight due to the refraction of electromagnetic waves in the atmosphere. Use a path clearance of at least 0.6 Fresnel zone to avoid excessive diffraction loss due to path obstructions. The formula is as follows:

$$R = ((\text{wavelength} \times d_1 \times d_2)/(d_1 + d_2))\,1/2$$

d_1 = the distance from the transmitter to the obstruction

d_2 = the distance from the obstruction to the receiver

Path clearances above 1.3 Fresnel zones can yield multipath propagation, nulls in received levels, and/or picture ghosts in the received pictures. Moving the antenna slightly can help alleviate the problem.

Spurious Emissions

Looking at the data that come with the translator is a good way to ensure the system is clean and clear unwanted emissions, except for harmonic products, which are undetectable by the test data measuring output performance. Low levels of distortion and high signal-to-noise ratios generally indicate clean transmission. The problem with unwanted emissions is that the undesirable products they generate fall inside *and* outside the assigned output channel.

When there are several stations located at one transmitter site where you are receiving interference, there may be harmonic mixes between the other stations that fall on or near your frequency. Sometimes these harmonics originate within the transmitters involved in the mix—and if the spurious harmonic signals are above a certain threshold, they may be in violation of governmental rules. The existence of this type of interference is verified by using a spectrum analyzer at the towers of the offending stations. The source of this kind of interference can only be verified by connecting test equipment to the various transmitters involved.

Most complaints are about interference to nearby television translators. Usually the harmonic stems from the television translator, not the FM translator. Any overloaded amplifier is subject to harmonic generation. Installing a high-pass filter at the output of the receive antenna might help. The advantage to going this route is that low loss of the filter does not compromise the integrity of the TV translator. This method could fail if the FM and TV translator antennas are just a few meters apart. If a filter does not work and the antennas are properly spaced, cabinet radiation or power line feedthrough is the culprit.

Spectrum Analyzers

Spurious emissions are not necessarily transmitter related. Spectrum analyzers can be unreliable when it comes to harmonic measurements if not used properly. Towers and other metallic objects can reradiate signals and cause nonlinear distortion, resulting in spurious emission.

Use a spectrum analyzer to examine the output channel. If the translator data sheet reveals solid data yet unwanted emissions are present, the cause is usually an adjacent channel. There are several courses of actions to resolve the issue. Use narrow-band filters in the I-F section of the translator, reduce the signal level of the interfering adjacent channel, or increase the level of the desired channel.

Desensing

Desensing is the result of brute power RF transmissions in the surrounding area. It is entirely possible to have a translator operating on 10 μV, for example, and a 100 kW station 1 km away. Intermodulation occurs when the translator tries in vain to accommodate the lower-level input signal while being hit by the much stronger signal, which runs into the first translator it sees. Filtering on the input line is the best way to solve the problem before the signals mix in the first place. If the site lacks a strong enough input signal to overcome the insertion loss of a selective filter, consider using special preamps designed just for that purpose. Relocating or redesigning the input antenna structure is another viable option. Other methods include raising the receive antenna, adding a preamp to overcome line loss, adding or stacking receive antennas, and relocating receive antennas (or perhaps the entire site).

After translator installation is complete and the power is turned on, there is nothing but hash and noise. But once the translator is off and the receiver is hooked up to the receive antenna, there is no problem. This is because any translator conveys undesirable products as well as the desired modulation. These products possess a wide bandwidth, which is usually several megahertz from the main carrier frequency. Generated products are comprised of the energy caused by the random motion of electrons (Johnson noise) and sideband components from the desired modulation. Generally, the undesirable products are quite weak, so they cannot be observed on a spectrum analyzer without suppressing the main carrier. Regardless of whether the undesirable products are modulation components or noise, some of these undesirable products will be in phase between the input and the output of the translator.

Problem Solving

Providing a filter at the translator's output can solve many problems. The purpose of the filter is to subdue those undesirable products that fall on the translator's input channel, but execution is more difficult than it sounds. Note that the quality factor, known simply as Q, ascertains how lossy the filter will be in operation.

If a translator operates at 100.1 MHz, it would need a filter to prevent undesirable products from falling on the input channel at 102.1 MHz. Two megahertz is the separation factor, so to make sure that no products from output fall on the input, the bandwidth cannot be more than 1 MHz. So $Q = 100.1/1 = 100.1$ is the minimum value. To have a filter with a low insertion loss and a minimum of energy loss, the Q for every element inside the filter has to be 100 times the minimum, or 10,000 times. But the realization of such a Q factor necessitates the use of costly cavity-type filters.

It is much more cost efficient to use Q factors of around 800 for the filter elements. The filter uses a combination of two techniques: bandstop and bandpass. The bandstop section is a slot about 300 kHz wide, adjusted to the input channel frequency.

The bandpass section passes carrier frequency and useful modulation data. This low-loss device adds more selectivity that optimizes the system's performance. It can also decrease the radiation of out-of-band signals. A good illustration would be between an antenna and transmitter combiner, where the filter's job is to overpower any harmonics originating in the ferrite isolators and downgrade any broadband transmitter noise so that receive sensitivity remains intact. Energy from the translator output that falls on the input frequency is attenuated by approximately 50 dB. Using an example of 5 μV worth of undesirable products falling on the input after passing through the filter, the magnitude is reduced by 50 dB (0.0158 μV the SNR $= 10/0.0158 = 632 = 56$ dB. Now performance is excellent.

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