

Synchronous FM Boosters

An Overview

An FM booster provides signal coverage to underserved areas not reached by a main transmitter due to intervening terrain obstructions. When properly designed and installed, a booster system improves the coverage of an FM radio station to serve listeners who have not previously received adequate signal. A booster is intended to provide a fill-in signal, not to extend a station's licensed ERP contour.

THE RULES

Maximum permissible booster power is 20 percent of a licensee's class maximum, except for 250 watts ERP within 200 miles of the Canadian border and 50 watts within 200 miles of the Mexican border.

A station is permitted to deliver its signal to a booster site by whatever means it finds suitable. Commonly used means include microwave STLs, Inter City Relay, telephone lines, dedicated cables and even fiber optics.

Off-air pickup of the main signal to feed an on-frequency FM booster is not effective because feedback and stability problems limit the booster amplifier's power output. The alternate delivery systems above are more practical and can provide continued booster operation even when the main transmitter goes off the air.

SYSTEM DESIGN IS CRITICAL

A synchronous FM booster system is intended to provide signal strength to areas that are shielded from the main transmitter by intervening terrain.

FCC Rules require that an FM booster not interfere with the primary signal within the community of license. If incorrectly designed, a booster system could cause large areas of overlap with the primary signal, causing serious degradation of reception in the overlap areas.

To avoid overlap, it is important to consider the booster site, terrain shielding, booster ERP, and antenna pattern in the design.

Figure 1 illustrates the coverage patterns for a San Francisco station's transmitters. The main transmitter is located on the San Francisco peninsula; the booster is located in a valley east of the city. While coverage in the valley is improved, reception in Marin County to the north deteriorates where the signals overlap. Careful design and planning could effectively eliminate the overlap area.

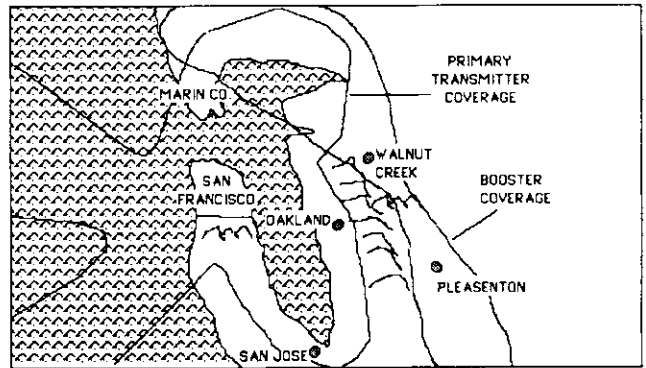


Figure 1.

Additionally, three conditions are necessary for successful booster systems:

- Transmitter frequencies must be synchronized
- Modulation must be synchronized
- Time delays must be added to accommodate differing STL and RF path lengths

When a system is properly engineered, isolation and synchronization of the primary and booster signals can be achieved to maximize coverage.

WHY NOT A TRANSLATOR?

A booster is preferred when increasing a station's signal strength within its defined contour. The broadcast frequencies of the primary and secondary signals are identical in a booster system; in translator systems they are different. Some of the limitations of translators include:

- Limited availability of new frequencies
- FCC restrictions limit translator power
- FCC restrictions limit advertising revenue
- Auto radios must be re-tuned to the translator's frequency when moving out of the main area.

RECEIVER CAPTURE RATIOS

When FM receivers are presented with multiple carriers that have nearly identical frequencies, main and booster signals for example, amplitude limiting circuitry will "capture" only the stronger signal.

For this capture effect to occur, the main and booster signal strengths must differ by 15 dB or more. If not, distortion and interference artifacts will be heard. Proper synchronization of the two signals, however, can reduce the capture ratio needed for clear reception to about 6 dB. Proper antenna placement and control of the RF power levels of the main

and booster transmitters can optimize the ratio of the two signal levels.

FREQUENCY SYNCHRONIZATION

Main and booster transmitters operating on the same broadcast channel will heterodyne or “beat” with each other and create unwanted tones in listener’s receivers. The tones will be 20 to 40 dB below the 100% modulation level and will be distracting to the listener.

These tones are unavoidable as long as there is a small frequency difference between the transmitters. The solution is to phase lock the carrier of each transmitter to a single reference timebase, an ultra-stable 19 kHz pilot signal in this case. This method is reliable and cost effective, and eliminates the need for additional spectrum to carry a reference signal. It does not require expensive, stable timebases at each transmitter nor does it require frequent frequency recalibration at each location.

MODULATION SYNCHRONIZATION

Two or more transmitters operating on the same frequency, even under phase-locked conditions but modulated at different levels by the same program material, can generate unacceptable noise in receivers. This noise sounds similar to multipath interference and is due to nonsymmetrical sidebands in the RF carrier spectrum of the two broadcast signals. The interference noise ranges from 20 dB to 60 dB below the peak modulation. It can be eliminated by using a single modulating source at the studio and then exactly replicating the modulation, or deviation, at each transmitter. TFT’s booster system guarantees that the peak frequency deviations at all sites are identical.

THE TFT FM BOOSTER SOLUTION: THE MODEL 8900 RECITER®

By using Intermediate Frequency (IF) repeating STL’s to directly convert the FM modulated signal from one frequency to another, multiple demodulation and remodulation processes which produce group delays in the baseband signals can be eliminated. Further, the modulation levels of the main transmitter and the boosters can be precisely identical.

The Model 8900 Synchronous FM Reciter® consists of a composite STL receiver, phase-locked loops and a 5-50 watt FM broadcast amplifier which enables the design of superior booster systems. Unique patented technologies which make this possible are:

- An ultra-high stability 19 kHz reference signal is used as the stereo pilot and the frequency synchronizing signal
- Direct frequency translation is used to eliminate the group delay inherent in demodulation and remodulation in conventional STL’s and FM exciters

- The modulation level (deviation) of the main transmitter is exactly repeated in all boosters.

In addition to synchronizing modulation and eliminating group delays, the Reciter® solution allows each transmitter’s frequency to be phase-locked to the common pilot signal. The pilot already exists in the FM stereo composite baseband signal and no additional spectrum or subcarrier is required to transmit it.

The benefits of the TFT FM booster solution include:

- There are no heterodyne tones in the system
- SNR and THD are not degraded by unequal modulation levels among transmitters
- No additional subcarrier is required for transmitting the reference signal
- There are no group delays in the baseband signal
- Better signal field strength is provided within the licensed contour.

A typical booster system is shown in Figure 2. The signal is transmitted from the studio to the main transmitter via STL. A Model 8900 Reciter® is used to excite the main transmitter and an IF repeating STL relays the signal to the booster site. An 8900 at the booster site drives an FM transmitter or an FM antenna.

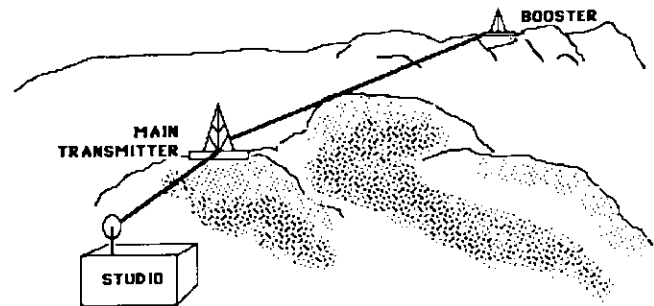


Figure 2.

THE STUDIO

As seen in Figure 3, an FM stereo generator and STL are located at the studio and transmit the composite FM baseband signal to the main transmitter site. The Model 8900 booster system accommodates the addition of subcarrier and MUX signals to the composite baseband.

The stereo generator is modified to accept a reference signal from the TFT Model 8921 ultra-stable 19 kHz Timebase Generator. The 19 kHz signal is generated from a crystal oscillator that has a long term stability of two parts per million per year. It serves as the pilot carrier for the composite stereo signal and provides the reference for phase-locking the carrier frequency of the main and booster transmitters.

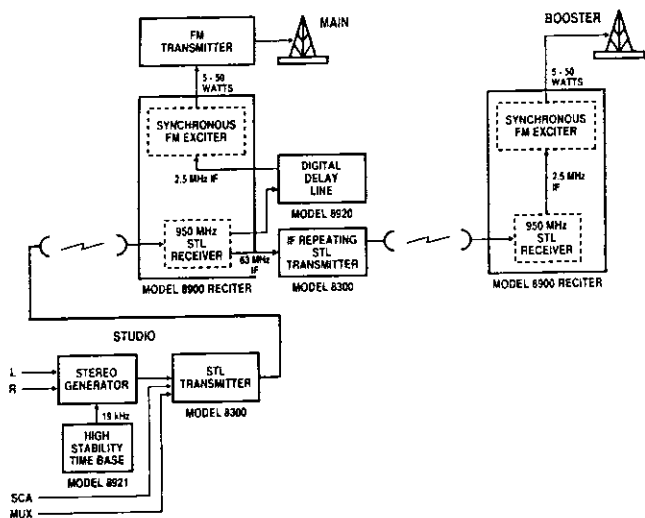


Figure 3.

THE MAIN TRANSMITTER

At the main transmitter site (Figures 2 and 3), a TFT Model 8900 Synchronous FM Reciter® receives the STL carrier and converts the RF signal to a frequency in the 88-108 MHz broadcast band. Its phase-locked loop system also precisely synchronizes the FM broadcast carrier frequency to the 19 kHz reference signal in the composite baseband.

The Reciter's® RF output drives the main FM transmitter and its 70 MHz IF output provides the signal for an IF repeating STL transmitter. This STL transmitter forwards the FM signal to one or more booster sites.

THE BOOSTER SITE

At the booster site, a TFT Model 8900 Synchronous Reciter® again receives the STL signal from the main transmitter. Its power output, adjustable from 5 to 50 watts, drives an FM transmitter or an FM antenna directly.

The Reciter's® 70 MHz IF output can be used to forward the FM signal to other booster sites by means of another IF repeating STL transmitter if desired.

If phase-locking to the 19 kHz pilot reference is not required, the Reciter® can stabilize its RF broadcast frequency to within 200 Hz by phase-locking the carrier to an internal oven-controlled oscillator.

TIME DELAY

The length of the signal path between the main transmitter and the booster including the STL paths must be considered when designing a booster system. Radio signals travel one mile in 5.4 microseconds. One or more microseconds difference in delay between the two signals in the overlap area can be detected by listeners.

TFT's Model 8920 Digital Delay Line is adjustable

from .1 to 400 microseconds and is inserted into the shorter path link. It delays the shorter path so that the signals arriving in the overlap area are time-synchronized with each other. The delay line is inserted between the 8900's IF output and IF input.

Figures 2 and 3 illustrate a typical serial booster system; figures 4 and 5 illustrate typical parallel booster systems with and without repeater STLs. Many other booster system configurations have been implemented using TFT's Synchronous FM Reciters® and IF repeating STL systems.

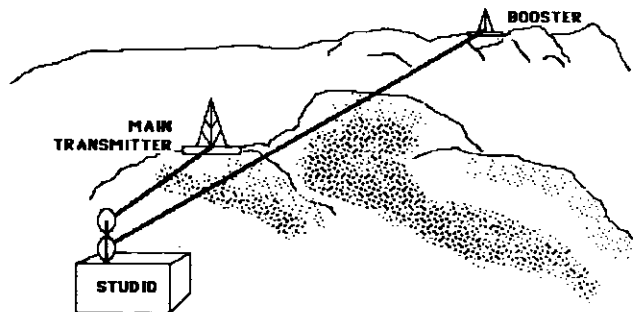


Figure 4.

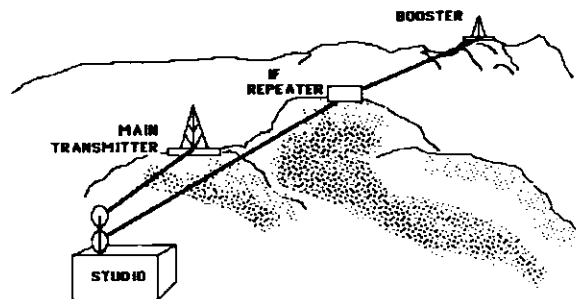


Figure 5.

Summarizing the advantages of TFT Reciter® booster systems:

- Carrier frequencies are precisely synchronized
- Modulation levels are precisely synchronized
- Transmission path delays are eliminated
- Less equipment is required than with other booster concepts
- Equipment, installation and maintenance costs are lower.

ENGINEERING STUDY

Stan Salek of Hammett & Edison, Inc., Consulting Engineers, conducted a booster study and presented a paper on the study at the National Association of Broadcasters Convention in Las Vegas, Nevada, in 1992. This independent study confirmed the advantages of using the TFT synchronous booster method. A copy of the paper is available on request.

Figure 6 illustrates a portion of the Hammett & Edison study model. It includes the interference zone and a potential area of improvement when time alignment methods are used.

The interference zone is defined by the shaded region between the boundaries of the main and booster contours that differ by 15 dB.

The unshaded band shows an example of the area that may be improved by time synchronizing the arrival of the main and booster RF signals. It is narrowest, about one mile across, when the signal ratio is 0 dB, increasing to about two miles for a 5 dB signal to noise ratio and to three miles for a 10 dB ratio. By adjusting the time delay, the area of improvement can be moved to any location within the interference region.

In this worst-case example, the potential improvement area is relatively small compared to the total interference area. In real environments that include hills, mountains or other high terrain between sites, most of the interference zone would most likely lie in unpopulated areas.

CONCLUSIONS

It has been a problem for many FM stations to transmit beyond geographical obstructions to provide adequate, clean signals for their listeners. Now, the TFT Synchronous FM Booster system can increase the listener base of many FM stations.

The heart of the system is the TFT Model 8900 Reciter[®], a combination Aural STL receiver and 88-108 MHz FM Exciter. The system synchronizes phase, RF delay and modulation levels to minimize interference due to overlapping signals.

FM stations throughout the United States and around the world are increasing their market share with the TFT 8900 Reciter[®] system.

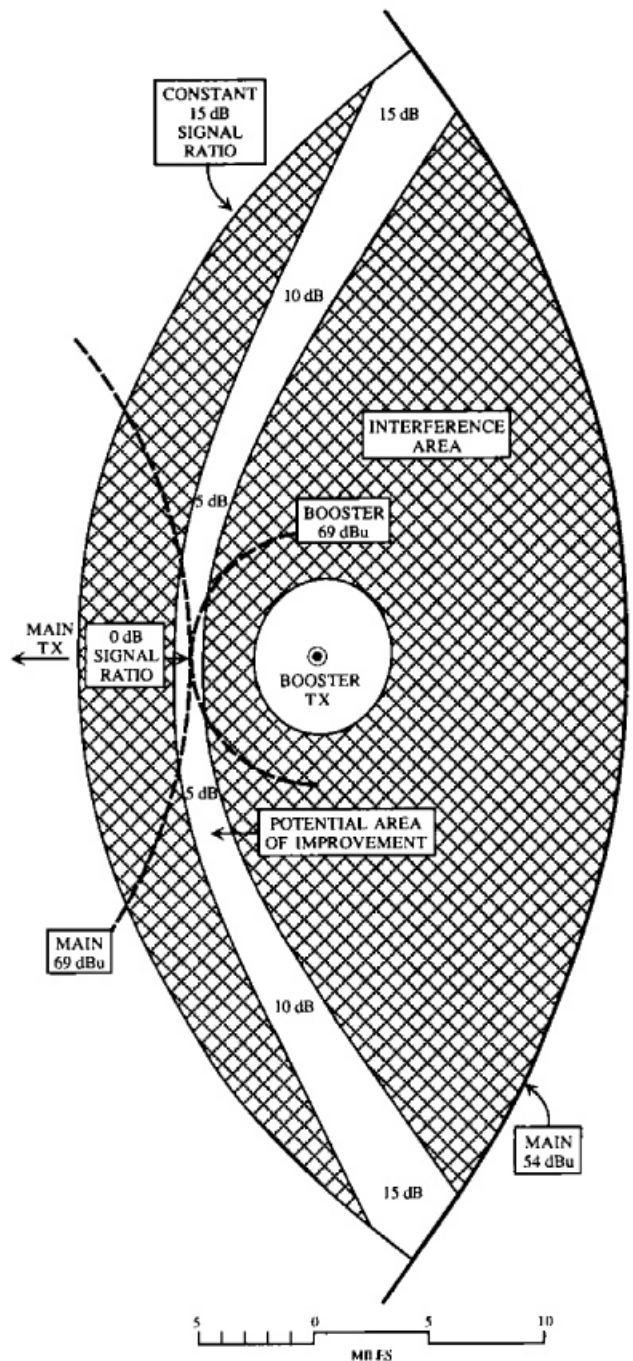


Figure 6.



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