Determining Signal Booster Output Power for In-Building Systems

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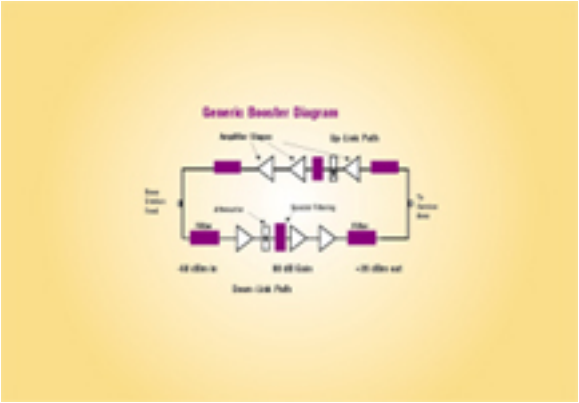
The FCC in CFR 47 part 90.219 approves signal boosters for use in the 800/900 MHz Land Mobile and Public Safety spectrum. This article discusses the deployment of Class B (broadband) signal boosters for in-building service improvement.

Due to their low cost and ease of installation, Class B signal boosters are being installed throughout the Americas to improve in-building radio communications. The booster's output power per signal will greatly influence the design of the distribution network (placement of antennas) and resultant coverage. Hence it is important to get an accurate estimate of the expected power per signal so that the system designer can plan an efficient distribution network that will provide the coverage desired at the lowest cost.

Normally there are three elements that influence the output power of a signal booster: the power level of the incoming signal, the gain of the booster, and the output power capability. There is, however, a fourth consideration that often impacts the final outcome, namely the number of signals that the booster is amplifying.

A quick review of the way a booster works will provide valuable insight into understanding these elements. On the downlink, the booster receives RF signals from a donor base site via a directional donor antenna located on the roof of the building. It then filters, amplifies and directs the RF signals into the service area via the distribution network. On the uplink, the mobile or portable radio signals are received via the same distribution network, filtered, amplified and directed back to the donor site via the directional donor antenna.

Since most signal boosters have a lower ERP (effective radiated power) per signal then the mobiles and portables they service (typical booster output may be +15 dBm while most portable handsets are capable of at least +27 dBm), the primary concern is the downlink power.



Boosters use Class A linear amplifiers to amplify multiple signals with reasonable intermodulation distortion (IMD). For example, a signal at -60 dBm and gain of 80 dB will yield an output signal of +20 dBm. Likewise, an input signal of -80 with 80 dB of gain will have an output signal of 0 dBm. The lower limit of usable signal is

limited in practice by the value of the signal when it has been amplified. Thus, a -100 dBm signal amplified by 80 dB (-20 dBm) will not propagate very far before it falls below the ambient noise floor.

The more common concern comes from the upper limit of signal level. The amplifiers in the gain path have a linear limit often referred to as composite power. This is the power that is available while meeting the FCC spurious emissions limit. Furthermore, this composite power must be shared by all of the signals in the pass band. In a simple example, a booster with a composite power of 1 watt would amplify 10 signals at .1 watt each (+20 dBm).

In reality, the typical power per signal is a bit less then stated above due to multiple signal IMD considerations. For a more accurate estimate, the EIA has established a formula (see below) for computing the maximum signal power while meeting the FCC limit on IMDi. Boosters that have output limiting capability (automatic gain control) will do the math and automatically adjust the gain to the approved output level. The key is to determine if the booster's output amplifiers can support the power that can be achieved with the input signal and booster's gain. This information should be in the manufacturer's specifications.

FORMULA

$$S = .667 [IP3 + .409 - 24.75 \log (N) + 1.437 \{\log (N)^2\}]$$

S = Maximum signal power
IP3 = third order intercept point of the amplifier
N = number of equal power channels

Some products do not automatically limit the power. Operating a 1-watt booster (1 dB compression point) at the same power level as a 1-watt booster (composite power) will produce twenty times the intermodulation distortion. The difference is in the compression point versus composite power. This issue is quite common, as power is often stated in a deceptive way.

Assuming the output level is achievable for the number of signals in the pass band, the downlink ERP will equal the incoming signal level plus gain. However, the fourth element in this analysis is the number of signals in the pass band that the booster must amplify. For an accurate count, the full number of signals at the donor base site should be considered. Even if the signals are not being used in the service area, they will still be seen by the booster's gain path. If all the signals can be amplified without limiting the output power, the coverage will be consistent regardless of the number of active signals. If not, the gain should be reduced to match the loaded output. Otherwise coverage will shrink when the donor base is transmitting on all channels.

Since it is possible for the booster to receive and amplify undesired signals, it is best to sweep the pass band with a spectrum analyzer and a donor antenna from the donor antenna location. Any signal 10 dB down from the desired signals will not impact the power sharing considerations. But signals at or above the desired signal will share the power and must be considered when estimating the booster's ERP. Exceptionally strong signals may overdrive the booster, causing the output limiting to reduce gain and the desired signal ERP.

The per signal ERP can be determined by knowing the power level of the incoming signal, the gain of the booster, and the power capability of the booster. With an accurate measure of ERP, and provided that the booster can handle the number of signals in the pass band, the distribution network designer will have a much higher

probability of achieving the desired coverage at the lowest design cost.

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