TECHNICALLY SPEAKING

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RF amplifiers—coming and going

When precautions are followed, both receivers and transmitters can get a boost

Radio frequency amplifiers are used on both receivers and transmitters. Generally, receivers incorporate an RF amplifier stage internal to the receiver. Sometimes, an additional amplifier is placed at a point ahead of the receiver to overcome a loss such as coaxial cable loss or multi-coupler loss. Amplifiers placed ahead of the actual receiver are generally called preamplifiers.

The final output stage(s) of an RF transmitter is an RF amplifier. Frequently, an additional RF amplifier is placed between the transmitter output and the antenna to boost the RF power level. Such an RF amplifier is called a power amplifier.

In this article we will look at how both of these types of RF amplifiers are used and how they affect the communication system.

Figure 1 shows a receiver that is connected to the antenna through a long run of coaxial cable. In this example the cable has a loss of 4 dB. The noise figure of the receiver is 9 dB. The noise figure of the receiving system is equal to the cable loss plus the noise figure of the receiver (4 dB + 9 dB = 13 dB). In an ideal receiving system with a noise figure of 0 dB, the noise power in a 1 Hz bandwidth is -174 dBm. Stated another way, this is -174 dBm per hertz (-174 dBm/Hz).

Equation 1:

$$N_C = 10\log B$$

(Where N_C is noise correction factor in decibels and B is bandwidth in hertz.)

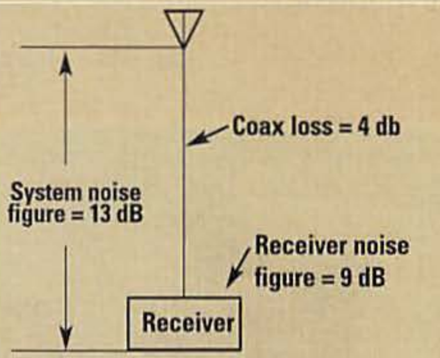


Figure 1: The receiver with a 9 dB noise figure preceded by a coaxial cable with a loss of 4 dB yields a total system noise figure of 13 dB.

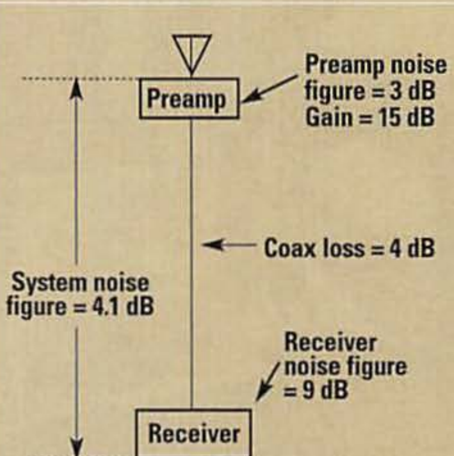


Figure 2: With the low-noise preamplifier installed at the antenna the receiver system noise figure becomes 4.1 dB. This represents a 9 dB improvement in the overall receiver system noise figure.

This example uses a conventional FM receiver operating in the narrowband (±5 kHz deviation) system with a sensitivity of 0.25μV at 12 dB SINAD. Typically, 12 dB SINAD is achieved at a signal-to-noise ratio (S/N) of approximately 4 dB. Because 0.25μV is -119 dBm (in a 50-ohm system), the noise floor of the receiver must be -123 dBm, approximately. Because the figure of -174 dBm/Hz is for a 1 Hz bandwidth, a correction factor must be used to adjust for other bandwidths. The correction factor is shown in Equation 1.

This receiver has a bandwidth of 15 kHz, so the correction factor is calculated using Equation 1 and found to be 41.76 dB. Thus, the noise floor of an ideal receiver with a bandwidth of 15 kHz is -132.24 dBm (-174 dBm + 41.76 dB). Because the receiver in this example has a noise floor of -123 dBm, it has a noise figure of approximately 9 dB.

With the 4 dB loss in the coaxial cable ahead of the receiver input, the system noise figure becomes 13 dB for a noise floor of -119 dBm. This means the signal at the input to the coaxial cable at the antenna has to be approximately 4 dB better, or -115 dBm.

In Figure 2 we see what can happen when we place a preamplifier ahead of the coaxial cable (for example, at the top of the tower). Suppose that the preamplifier has a gain of 15 dB and a noise figure of 3 dB. The new system noise figure becomes 4.1 dB. This is equivalent to a noise floor of approximately -128 dBm. This means that the signal input to the system must be -124 dBm to achieve 12 dB SINAD sensitivity.

Notice that this is 9 dB better than it was without the preamplifier. This is also equal to the improvement in the overall system noise figure.

A tower-top preamplifier doesn't always yield such great results. For example, if the ambient noise level at the communication site is high, the improvement generated by a tower-top preamplifier is less dramatic. Generally, the higher the ambient site noise level, the smaller the net improvement offered by the preamplifier. With high site noise levels, a preamplifier is practically useless, as the ambient noise is amplified alongside the signal, resulting in no improvement in the signal-to-noise ratio. The signal-to-noise ratio at the input to the receiving system is the *real* measure of improvement.

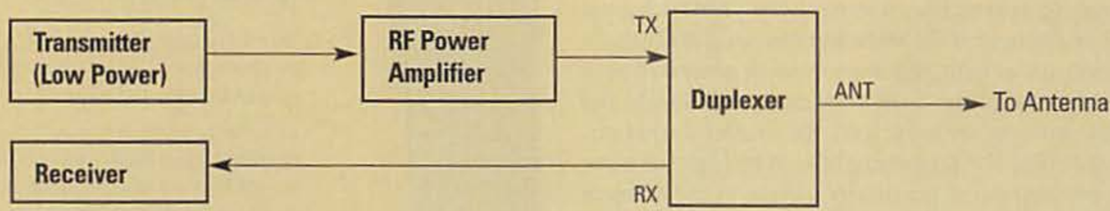
Try to choose an RF preamplifier with a low noise figure and a high third-order intercept point (this is a measure of the intermodulation rejection figure of the amplifier). In high signal-level areas, preamplifier use may result in more severe intermodulation and receiver-desense problems. Intermodulation products formed in the receiver may be just below the threshold of interference without the preamplifier. With the preamplifier in line, the levels of the input signals will drive the intermodulation product(s) to a level sufficient to cause nuisance or destructive interference. The same thing is true of desense. Potential desense problems may lie just beneath the surface without the preamplifier but become quite apparent after installation. Be aware of these potential problems before deciding whether to use a preamplifier.

The higher the ambient site noise level, the smaller the improvement offered by the preamplifier. With high site noise levels, a preamplifier is practically useless.

A power amplifier also may be used to boost the RF output power level of the transmitter. For example, the output of a handheld unit installed in a vehicular adaptor is only a few watts. However, by using an RF power amplifier, the output level can be boosted to a level comparable to a regular mobile transceiver. Or, a 10- to 25-watt base station can be boosted to a much higher power level using an RF power amplifier.

RF power amplifiers can be classified as broadband or narrowband. The broadband units usually need no tuning when used at the proper frequency. However, narrowband units will need to be tuned for the particular frequency or

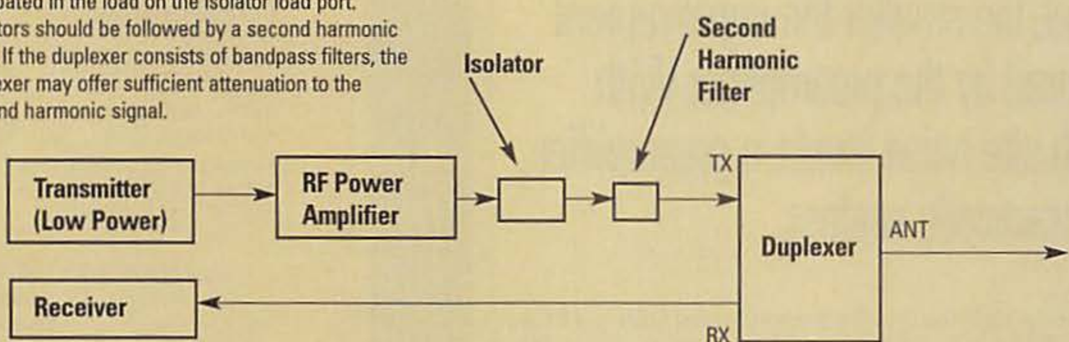
Figure 3:



This is a typical repeater arrangement. The RF amplifier may not like the load presented by the input to the duplexer. The line length between the duplexer and the RF amplifier output may be changed to improve the load impedance to the RF power amplifier.

Figure 4:

An isolator is used to present a proper 50-ohm impedance to the RF power amplifier. Although a mismatch may still exist, the RF power amplifier sees a 50-ohm impedance. Any reflected power will be dissipated in the load on the isolator load port. Isolators should be followed by a second harmonic filter. If the duplexer consists of bandpass filters, the duplexer may offer sufficient attenuation to the second harmonic signal.



narrow band of frequencies over which the amplifier must operate. In the case of a transceiver, the RF amplifier must have a bypass that allows the receive signal to pass through the amplifier in the reverse direction with little attenuation.

RF power amplifiers are designed to work into a purely resistive load of 50 ohms. Highly reactive loads—such as an improperly tuned antenna, cavity filters and duplexers—may cause the amplifier to become unstable. Sometimes the length of the coaxial line between the RF amplifier and the duplexer or antenna can be changed to reflect a better load to the RF amplifier output. Changing the line length simply tunes out the reactive component of the load impedance.

Figure 3 shows a typical repeater/base station using an external RF power amplifier. Changing the line length between the duplexer and RF power amplifier sometimes helps to present a better load condition to the output of the amplifier.

An alternative is shown in Figure 4.

Using precautions associated with receiver preamplifiers and transmitter power amplifiers can prevent many headaches.

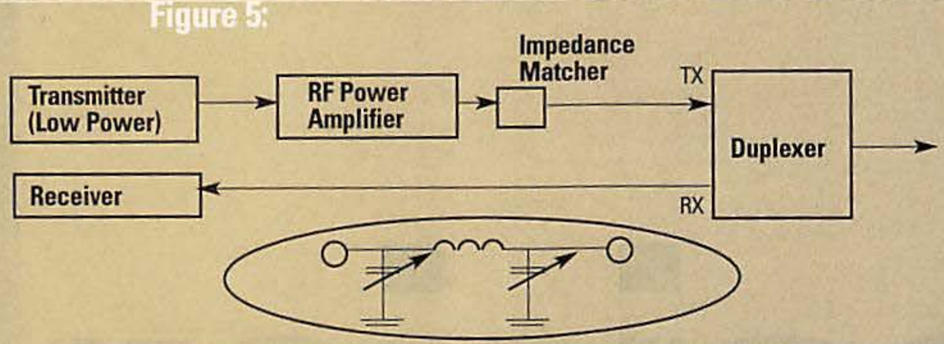
An RF isolator can be used between the RF amplifier output and the duplexer or load. The output of the RF amplifier "sees" a good 50-ohm match even though a mismatch may exist between the isolator and the load. Any reflected power is dissipated in the load resistor connected to the load port of the isolator. Normally, a second harmonic filter follows the output of the isolator, since ferrite materials tend to generate second harmonics. Don't connect an isolator to the output of a transceiver—it will block the receiver input. The isolator must be connected only to the transmitter or power amplifier output.

Yet another alternative is shown in Figure 5. Here, an impedance matcher (pi-network) is connected between the output of the RF amplifier and the load impedance. The pi-network can be tuned so that the RF amplifier "sees" a 50-ohm load impedance.

In addition to understanding how RF amplifiers may be used to improve the performance of a communication system, it is also crucial to understand how to properly use them. Important precautions that should be followed include:

- Do not overdrive the input

Figure 5:



An impedance matcher such as the pi-network shown in the inset can be used to provide a proper match to the RF power amplifier. Such impedance matchers are designed to mount right on the output connector of the RF amplifier. Tuning adjustments are accessible through small holes usually covered by caps to keep dust and other foreign matter out of the device.

of the amplifier

- Make sure the amplifier "sees" a proper 50-ohm load impedance
- Do not exceed the DC input current or voltage rating of the amplifier
- Make sure the amplifier has adequate ventilation in mobile installations
- Make sure the amplifier cooling fans are operating
- Don't just check the power out put with a wattmeter; check it with a spectrum analyzer

Using the proper precautions associated with both receiver preamplifiers and transmitter power amplifiers can prevent many headaches. In the proper situation, both of these devices can improve the communication system. Used improperly, either of these devices can cause serious problems.

Until next time—stay tuned! ■

Harold Kinley's latest book, "The Radioman's Manual of RF Devices," is available from Noble Publishing. Visit www.noblepub.com to order.