Repeater Receiver Performance Evaluation

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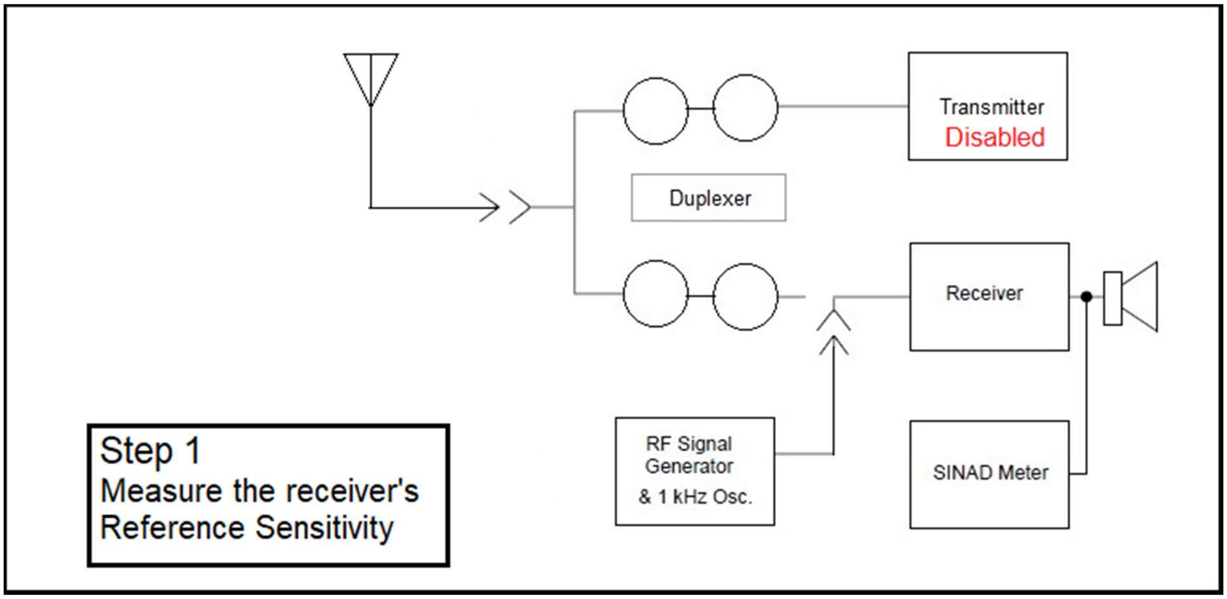
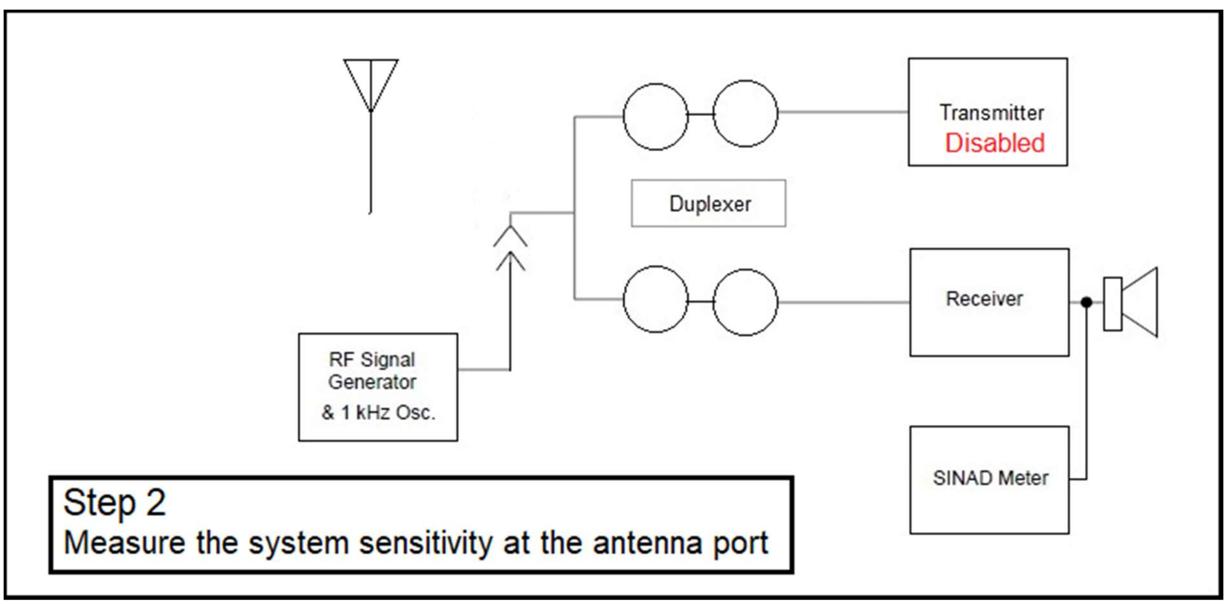
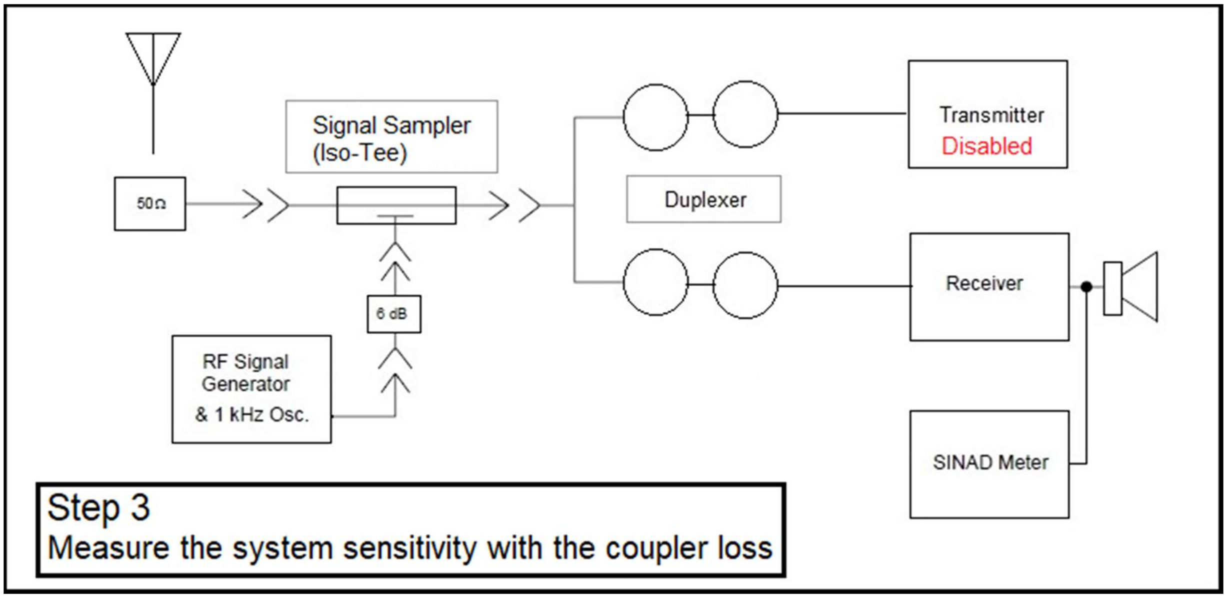
Repeater receive performance should be comprehensively evaluated at the time a system is installed and at regular maintenance intervals thereafter. This performance evaluation procedure will identify most problems and will produce results that can be added to the system records.



Measure the receiver's sensitivity with the repeater's transmitter disabled. Reference sensitivity is the value in the manufacturer's specifications. If the sensitivity is specified in microvolts, convert that to dBm and conduct all measurements in this procedure in decibels. For example, a typical sensitivity specification for 12 dB SINAD could be 0.25 uv which is -119 dBm.

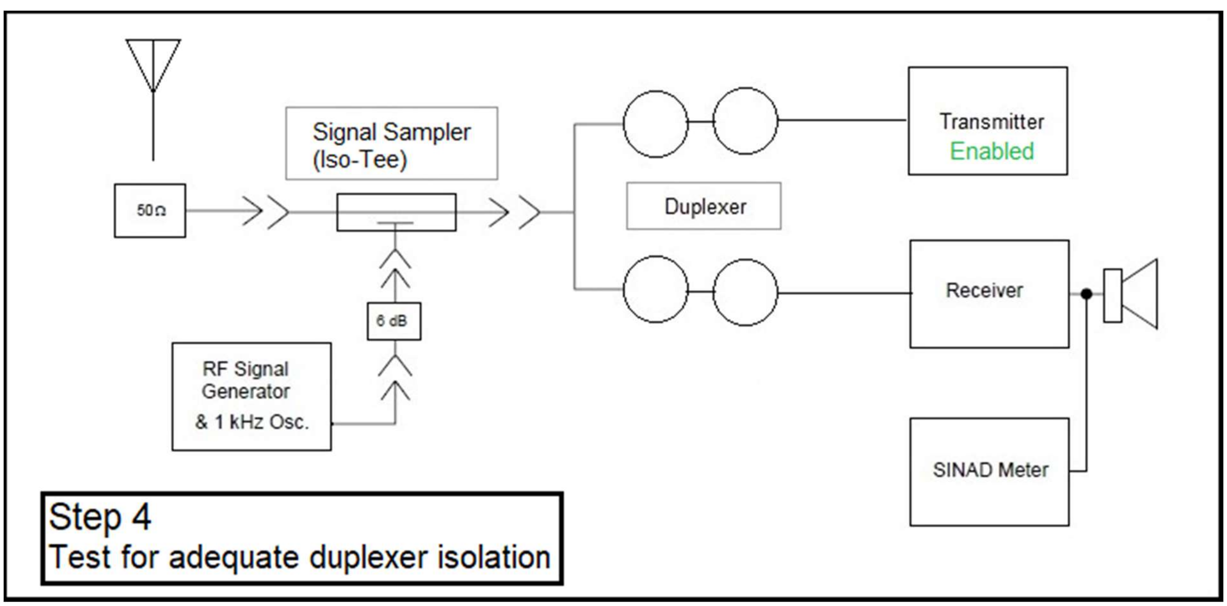


With the repeater's transmitter disabled, measure the system receive sensitivity at the antenna input. This will confirm duplexer and cable insertion losses.

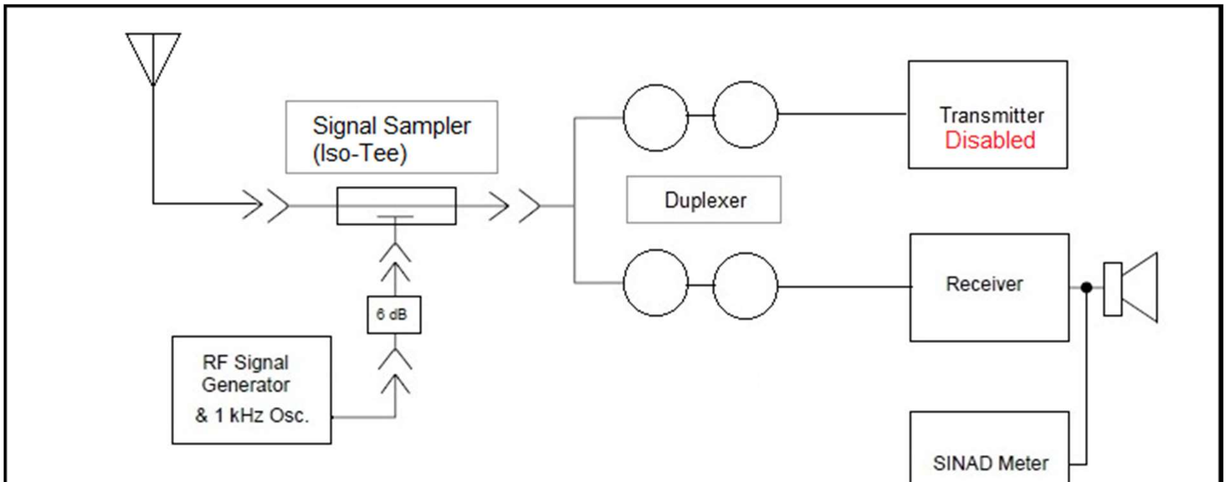


Connect a sampler and load as shown. With the repeater's transmitter disabled, increase the generator level to achieve 12 dB SINAD.

This is the reference sensitivity reduced by the loss of the coupler. This baseline value will be used in subsequent degradation tests.

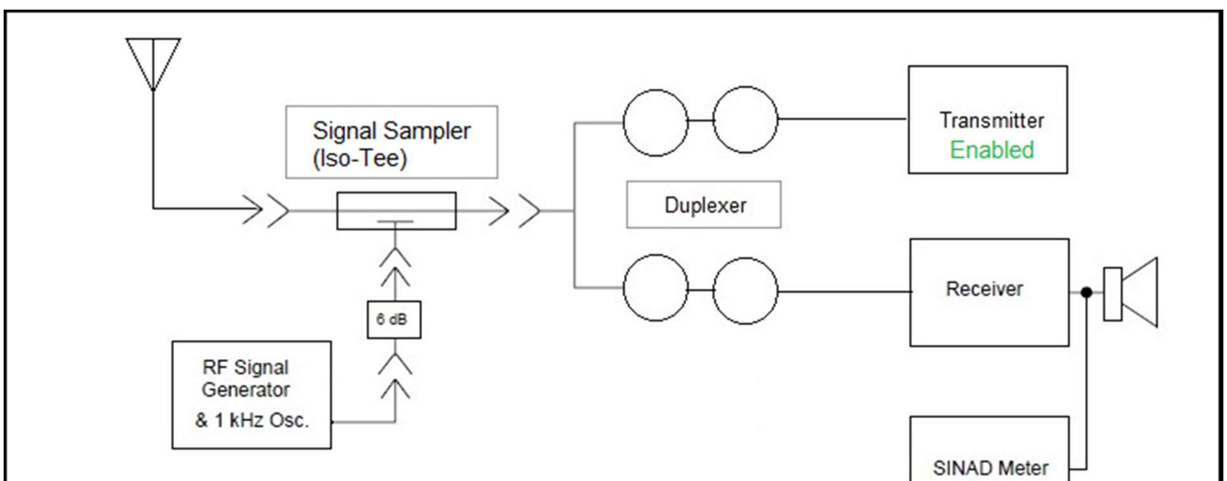


With the repeater's transmitter enabled, it should not be necessary to increase the generator level to maintain 12 dB SINAD. This test identifies any receiver degradation due to insufficient duplexer isolation.



Step 5
Test for receiver degradation due to site noise

Replace the load with the antenna. If it is necessary to increase the generator level to maintain 12 dB SINAD, the receiver is being degraded by the RF environment at the site.



Step 6
Test for added degradation from repeater transmitter

With the transmitter enabled, there should be no increase in the measured receiver degradation.

Notes

① The signal generator and SINAD meter are shown symbolically in the drawings as separate devices. In many cases, these will be functions included in a service monitor or communications system analyzer.

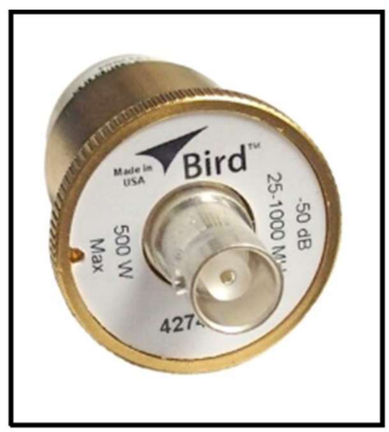
② Use of the instrument's power capable RF I/O port is recommended to protect the instrument against damage caused by accidental application of transmit power. Use the same generate port for all tests.

③ RF test cables used in these tests should be made of high quality double shielded coax such as RG-142 or RG-400.

④ Steps 3 and 4 require a dummy load. This should be a high-quality device capable of continuous dissipation of the transmitter's power and it should have excellent VSWR / Return Loss. (e.g. Bird Termaline)

⑤ Steps 3 through 6 require the use of a device to couple the test signal into the receive path without disturbing existing signals and/or noise. This is usually a signal sampler (often referred to as an Iso-Tee) although experienced technicians sometimes use a directional coupler.

Three examples of signal samplers are shown here.



The sampler in the left image is made by FXR. It has type N-M and N-F connectors on the main line so that it is 'insertable' if the system being tested uses type N connectors.

The Bird 4275-020 in the center picture uses Bird QC connectors so it can easily be configured for whatever type connector the system being tested uses.

Use a sampler with connectors that match the system being tested so that no between-series adapters are required

Both of these signal samplers are adjustable. A setting of 50 dB of isolation is suggested for these tests.

Signal samplers usually couple the test port to the main line capacitively which means that there is no termination for the instrument that is connected to the test port. Placing an in-line 5 to 10 dB attenuator on the test port will improve the match seen by the generator.

The third sampler example shown is an 'element' that fits in a Bird thruline wattmeter. Many technicians prefer the convenience of this type of sampler. The thruline wattmeter can be inserted between the duplexer and the antenna transmission line for measurement of transmitter power and to perform forward / reflected power antenna tests. Then the RF power element can be removed from the wattmeter and the sampler element installed to perform receiver tests.

⑥ Before conducting the test in step 4, inspect the cables that comprise the duplexer's harness to be sure that they are in good condition and that all connectors are properly tightened Also be sure that the cables from the duplexer to the repeater are made of high quality double shielded coax, Superflex, or Heliax and that all connections are properly tightened.

The test in step 4 verifies that the duplexer is operating properly and that it provides adequate isolation. If receiver degradation is observed with this test, the duplexer's alignment should be tested. The results should meet the manufacturer's specifications. Four cavity duplexers usually provide about 80 dB of isolation whereas six cavity duplexers can provide 100 or more dB of isolation. 80 dB of isolation may be sufficient for high quality repeaters to operate without desense but many systems will require more.

⑦ In step five, the receiver will be exposed to the RF environment at the site. If degradation is observed, receiver blocking caused by high-level in-band carriers should be ruled out first with a spectrum analyzer. In the absence of high level in-band carriers, the usual cause of receiver degradation is "site noise".

Site noise is an aggregate of environmental noise and site related noise. Environmental noise is the noise which would be present if this system's antenna were the only thing at that location. It originates from a variety of sources such as ignition systems, motors, lighting systems, computers, and electrical power distribution.

Environmental noise may appear to be uniform (white) across a limited range of frequencies such as the two-meter band, but it diminishes in amplitude with increasing frequency such that it is often not a problem above 400 MHz.

Environmental noise varies over time and with the type of location – rural, suburban, or urban. Most VHF systems will experience some receiver degradation due to environmental noise. Professional system planners always consider environmental noise when performing coverage studies for VHF systems.

Site related noise originates from equipment or devices located at the site. These may be intentional radiators such as two-way systems, cellular providers, or wireless internet services. Noise can also originate from unintentional radiators such as lighting systems, HVAC systems, data processing equipment, etc.

The site noise level is typically referenced to the antenna demarcation – the point at which the repeater system connects. Usually, this point is just beyond the coax entry into the shelter and after the surge protector. This is also the point where antenna testing is performed such as forward/reflected power measurement, return loss, and distance-to-fault.

The test in step five measures the degradation that the total site noise has on the receiver. Effective sensitivity is the system sensitivity measured in step two reduced by the value determined in step five.

For example, if it is necessary to increase the generator level by five dB to maintain 12 dB SINAD, there is 5 dB of degradation. If the receiver's reference sensitivity is -119 dBm and the duplexer loss + cable loss is 2 dB, the system sensitivity is -117 dBm at the antenna demarcation. The measured degradation reduces that to an effective system sensitivity of -112 dBm

Despite many statements to the contrary, 5 dB is not the "site noise" or the site "noise floor". It is the amount of receiver degradation due to site noise. The actual site noise level can be computed from the measurements in this procedure. (See Appendix)

⑧ If the repeater operated without desense when transmitting into a load in step 4, it seems logical that it would also operate without additional desense when transmitting into the antenna in step 6, however, in step 4 there could be some transmitter noise present at the receiver input at a low enough level that there is no apparent receiver degradation.

In step 6, when this noise sums with site noise and the intrinsic receiver noise (due to the receiver's noise figure), the total noise could result in a slight increase in degradation. Whatever increase in degradation is present further reduces the system effective sensitivity.

A significant increase of degradation in step 6 is often caused by a problem in the antenna system such as a cracked element or a fault in the supporting structure or mounting hardware. In such cases, high level RF from the repeater's transmitter can 'illuminate' one of these points and cause micro-arcing which results in generation of broadband noise that degrades the receiver.

The following table shows a typical example test result

Step	Generate Level	Notes
1	-119 dBm	Reference sensitivity specification
2	-117 dBm	2 dB duplexer & cable loss
3	-61 dBm	56 dB coupler loss
4	-61 dBm	No desense
5	-56 dBm	5 dB of site noise degradation
6	-55 dBm	Minimal additional degradation

System Effective Sensitivity = -111 dBm

Appendix

The site noise level can be determined from the effective sensitivity tests. The process starts with a review of some basics:

▪ <u>Noise levels must be stated in a specific bandwidth or as spectral power density</u>.

▪ The difference in noise power between two bandwidths is: Δ = 10 log [BW2/BW1]

▪ Reference sensitivity is the signal level required for a receiver to recover the modulation content to a standardized quality (the reference), for example 12 dB SINAD.

▪ Every modulation format requires a signal with a known C/N to demodulate the reference.

▪ 4 dB C/N is required for an analog FM receiver (±5 kHz) to deliver 12 dB SINAD

▪ For the example receiver with reference sensitivity of -119 dBm, the receiver noise floor (demodulator noise floor) is -119 dBm – 4 dB = -123 dBm

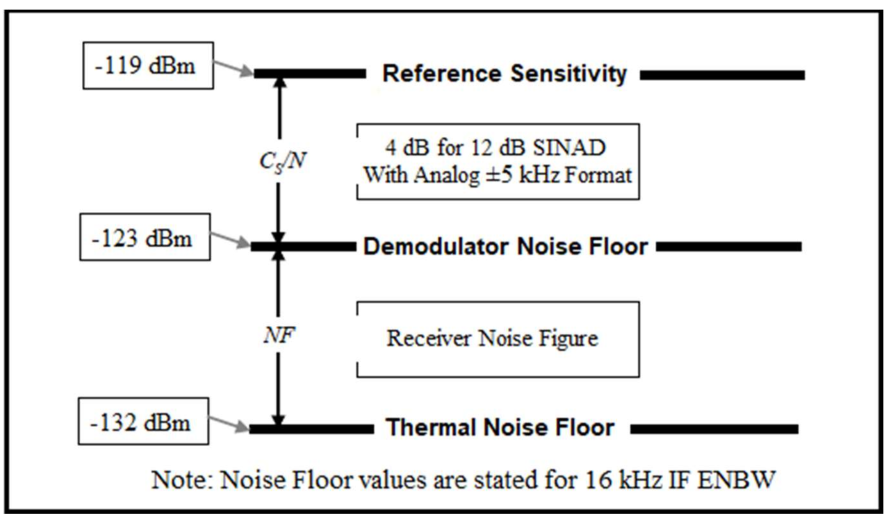
▪ The noise floor (N) in receiver C/N is based on the bandwidth of the receiver's IF filter.

▪ IF filter bandwidth is stated in terms of Equivalent Noise Bandwidth (ENBW)

▪ The ENBW for an analog FM (±5 kHz) receiver IF, is 16 kHz

▪ The thermal noise floor (n=kTB) is: -174 dBm/Hz

▪ For 16 kHz ENBW, the thermal noise floor is -174 + 10 log (16000) or -174 + 42 = -132 dBm



The diagram at left graphically shows the relationship of the above parameters.

If the receiver were an 'ideal' device, the demodulator noise floor would be the thermal noise floor.

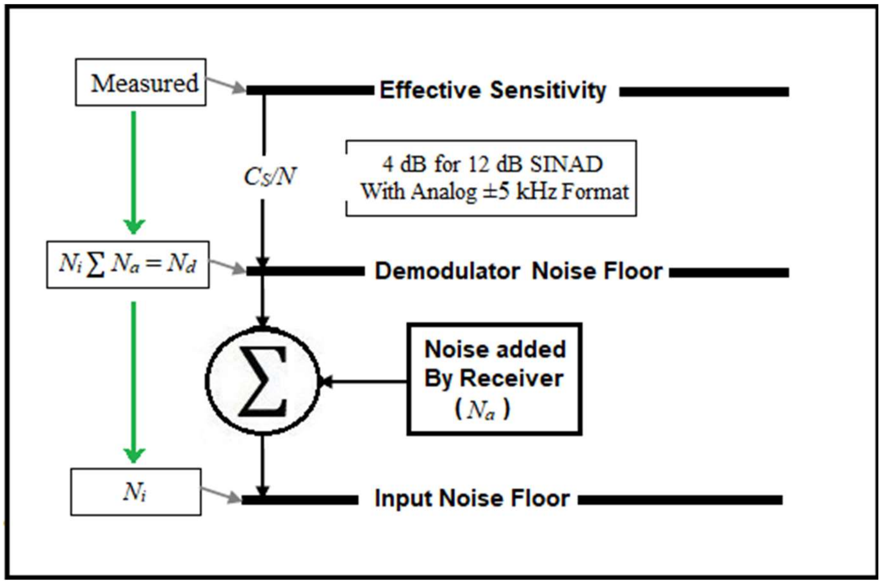
Real receivers contribute some intrinsic noise, thereby degrading the input C/N. The difference between the thermal noise floor and the receiver (demodulator) noise floor is the receiver's Noise Figure. Thus, if N_i = noise at the antenna input and N_d = noise at the demodulator, the relationship can be written as: N_i(dBm) + NF(dB) = N_d(dBm)

Significantly, this relationship is only valid when N_i = the thermal noise floor. However, by defining N_a as the noise added by the receiver circuitry, the equation can be restated as:
$N_i + N_a = N_d$ where all three terms are in dBm

To add two powers expressed in dBm requires that the terms first be converted to linear, the addition performed, and the result be converted back to dBm. There are calculator apps available to perform the math.

To show that noise powers must be summed in linear terms rather than added in decibels, the equation can be written: $\sum (N_{i\,+}\,N_a) = N_d$

For the example receiver with a 9 dB Noise Figure and N_i = the thermal noise floor, the equation can be solved for N_a: $N_a = N_d$ less N_i or -123.58 dBm.



The diagram at left shows the same receiver sensitivity and noise floor relationships as the previous diagram but the term Noise Figure has been replaced by the term Noise added. (N_a)

As shown here, the diagram illustrates how to determine the input noise floor based on the measured effective sensitivity.

Solving for the example of 5 dB or degradation due to site noise:

SITE NOISE FLOOR CALCULATION	
Reference sensitivity	-119.00 dBm
Degradation	5.00 dB
Effective Sensitivity	-114.00 dBm
Less required C/N	4.00 dB
Calculated Nd	-118.00 dBm
Less Na	-123.58 dBm
Calculated Ni	-119.41 dBm

Subtracting the measured degradation from the reference sensitivity gives the effective sensitivity.

The required C/N subtracted from the effective sensitivity gives the receiver's demodulator noise floor.

Subtracting the receiver' intrinsic noise (N_a) from the demodulator noise floor leaves the input noise floor N_i.

For the example system, the thermal noise floor at the receiver input is -119.4 dBm in 16 kHz bandwidth. With 2 dB of duplexer and jumper loss ahead of the receiver, the system effective sensitivity is -112 dBm and the noise floor at the antenna demarcation is -117.4 dBm.

This is -159.4 dBm/Hz or 14.6 dB above kTB.