RECEIVER TESTS

Two tone and spurious response (single signal) receiver tests should be performed on EW and radar receivers to evaluate their spurious free dynamic range. A receiver should have three ranges of performance: (1) protection from damage, (2) degraded performance permitted in the presence of a strong interfering signal(s) and no degradation when only a strong desired signal is present, and (3) full system performance.

The original MIL-STD-461A design requirement and its companion MIL-STD-462 test requirement specified four receiver tests. These standards allowed the interfering signal(s) to be both inband and out of band, which is meaningful for design and test of EW receivers, however inband testing generally is not meaningful for narrowband communications receivers. These standards were difficult to follow and had to be tailored to properly evaluate the EW and radar system. MIL-STD-461B/C still allowed the interfering signal(s) to be both inband and out of band but deleted the single signal interference test (CS08 Conducted Susceptibility test). MIL-STD-461D/-462D leave the pass/fail criteria entirely up to what is listed in the individual procurement specification. It also places all interfering signals out of band, redesignates each test number with a number "100" higher than previously used, and combines "CS08" as part of CS104. Therefore, to provide meaningful tests for EW and radar systems, the procurement specification must specify the three ranges of performance mentioned in the beginning of this section and that the tests are to be performed with the interfering signal(s) both inband and out of band. The four tests are as follows (listed in order of likelihood to cause problems):

Test Name	MIL-STD-461A	MIL-STD-461D
Undesired, Single signal interference test	CS08	Part of CS104
Desired with undesired, two signal interference tests	CS04	CS104
Two signal intermodulation test	CS03	CS103
Two signal cross modulation test	CS05	CS105

The rest of this section explains the application of these tests and uses the names of the original MIL-STD-461A tests to separate the tests by function.

TEST SETUP

A directional coupler used backwards (as shown here in Figure 1) is an easy way to perform two signal tests. The CW signal should be applied to the coupling arm (port B) since the maximum CW signal level is -10 dBm. The pulse signal should be applied to the straight-through path (port C) since the maximum pulse level is +10 dBm peak. These power levels are achievable with standard laboratory signal generators, therefore one doesn't have to resort to using amplifiers which may distort the signals. Always monitor the output signal to verify spectrally pure signals are being applied to the test unit. This can be accomplished by another directional coupler used in the standard configuration. Dissimilar joints or damaged or corroded microwave components can cause mixing. This can also result if the two signal generators are not isolated from one another. Therefore, even if a directional coupler is used to monitor the signal line, it

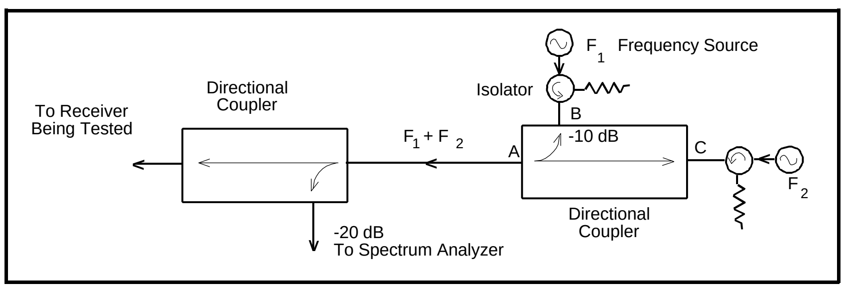

Figure 1. Receiver Test Setup When Antenna Can Be Removed

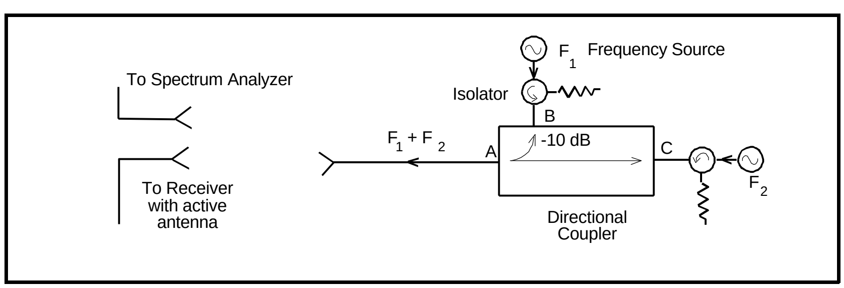

Figure 2. Receiver Test Setup When Antenna Is Active

is still advisable to directly measure the input to the receiver whenever there is a suspected receiver failure. This test does not need to be performed in an EMI shielded room and is more suitable for a radar or EW lab where the desired signals are readily available. If the receiver's antenna is active or cannot be removed, a modified test as shown in Figure 2 should be performed. The monitoring antenna which is connected to the spectrum analyzer should be the same polarization as the antenna for the receiver being tested. Amplifiers may be required for the F_1 and F_2 signals. It is desirable to perform this test in an anechoic chamber or in free space.

In the following discussion of CS08, CS04, CS03, and CS05 tests, it is assumed that when the receive light illuminates, the receiver identifies a signal that matches parameters in the User Data File (UDF) or pre-programmed list of emitter identification parameters. If a receiver is different, the following procedures will have to be appropriately tailored. If the UDF does not have entries for very low level signals in the 10% and 90% regions of each band, complete testing is not possible. Most problems due to higher order mixing products and adjacent band leakage are only evident in these regions. In the following tests, the lowest level where the receive light is constantly on is used to identify the minimum receive level. If a receiver has a receive level hysteresis or other idiosyncracy, then using a 50% receive light blinking indicator may be more appropriate. Whatever technique is appropriate, it should be consistently used during the remainder of the test. The maximum frequency for testing is normally 20 GHz. If a millimeter wave receiver is being tested, the maximum frequency should be 110 GHz.

CS08 - UNDESIRED, SINGLE SIGNAL INTERFERENCE TEST

MIL-STD-461B/C (EMI design requirements) deleted this test. MIL-STD-461D allows a single signal test as part of CS104 (CS04) but specifies it as an out of band test. The original CS08 inband and out of band test is still needed and is the most meaningful test for wide band EW receivers which have a bandwidth close to an octave. This test will find false identification problems due to 1) lack of RF discrimination, 2) higher order mixing problems, 3) switch or adjacent channel/band leakage, and 4) cases where the absence of a desired signal causes the receiver to search and be more susceptible. In this latter case, a CS04 two signal test could pass because the receiver is captured by the desired signal, whereas a CS08 test could fail. Examples of the first three failures are as follows:

EXAMPLE 1

A 2 to 4 GHz receiver which uses video detection (e.g., crystal video) and doesn't measure RF is used for this example. This receiver assumes that if the correct Pulse Repetition Interval (PRI) is measured, it is from a signal in the frequency band of interest. Three cases can cause false identification. Refer to Figure 3.

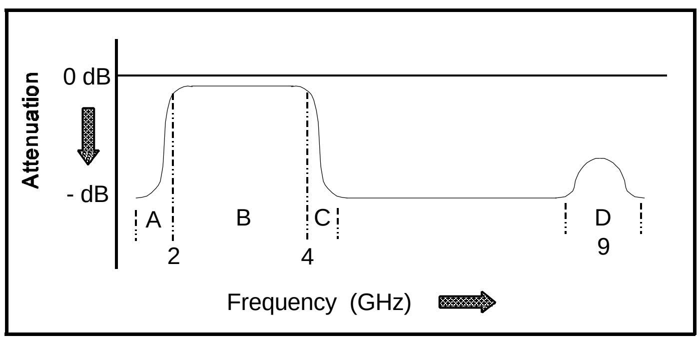

Figure 3. Frequency Areas in a Sample 2-4 GHz Receiver

(1) Region A&C. The 2 to 4 GHz band pass filter will pass strong signals in regions A&C. If they have the correct PRI, they will also be identified.

(2) Region B. Any other signal besides the desired signal in the 2 to 4 GHz region that has the correct PRI will also be identified as the signal of interest.

(3) Region D. Band pass filters with poor characteristics tend to pass signals with only limited attenuation at frequencies that are three times the center frequency of the band pass filter. If these signals have the correct PRI, they will be incorrectly identified.

High duty cycle signals (CW or pulse doppler) in regions A, B, C, and D may overload the processing of signals, saturate the receiver, or desensitize the receiver. This case is really a two signal CS04 test failure and will be addressed in the CS04 section.

EXAMPLE 2

A receiver measuring the carrier frequency of each pulse (i.e. instantaneous frequency measurement (IFM)) and the PRI is used for this example. False signal identification can occur due to higher order mixing products showing up in the receiver pass bands. These unwanted signals result from harmonics of the input RF mixing with harmonics of the Local Oscillator (LO). Refer to Figures 4 and 5.

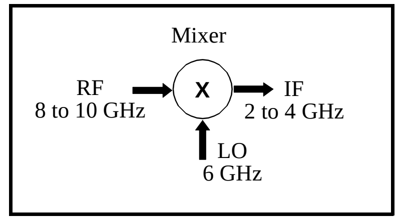

Figure 4. Low Side Mixing

Mixers are nonlinear devices and yield the sum, difference, and the original signals. Any subsequent amplifier that is saturated will provide additional mixing products.

If a 8.5 GHz signal with a 1 kHz PRI is programmed to be identified in the UDF, measurements are made at the 2.5 GHz Intermediate Frequency (IF), i.e., RF-LO = IF = 8.5-6 = 2.5 GHz.

The same 2.5 GHz signal can result from an RF signal of 9.5 GHz due to mixing with the second harmonic of the LO i.e., 2 X 6 - 9.5 = 2.5 GHz. This signal will be substantially attenuated (approximately 35 dB) when compared to the normal IF of 9.5 - 6 = 3.5 GHz. If the receiver has filters at the IF to reduce the signal density and a filter has minimum insertion loss at 2.5 GHz and maximum insertion loss at 3.5 GHz, then only the low level 2.5 GHz signal will be measured and assumed to be due to a 8.5 GHz input signal whereas the input is really at 9.5 GHz.

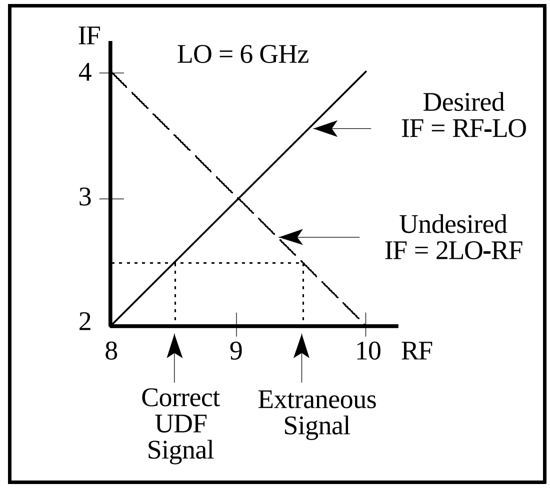

Figure 5. Low Side Mixing Results

Table 1. Intermodulation Product Suppression

Harmonic of LO	Harmonic of RF	Suppression
1	1	0
1	2	ΔP-41
1	3	2ΔP-28
2	1	-35
2	2	ΔP-39
2	3	2ΔP-44
3	1	-10
3	2	ΔP-32
3	3	2ΔP-18
4	1	-35
4	2	Δ-39
5	1	-14
5	3	2ΔP-14
6	1	-35
6	2	ΔP-39
7	1	-17
7	3	2ΔP-11

Courtesy Watkins-Johnson

Spurious intermodulation products can also result from high side mixing, but generally the suppression of undesired signals is greater. In this case, the LO is at a frequency higher than the RF input. This is shown in Figures 6 and 7.

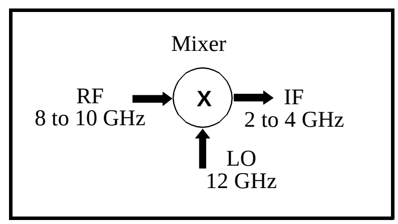

Figure 6. High Side Mixing

As previously mentioned, the amplitude of intermodulation products is greatly reduced from that of the original signals. Table 1 shows rule of thumb approximate suppression (reduction), where $\Delta P = P_{RF}(dBm) - P_{LO}(dBm)$. As can be seen, the strength of the LO is a factor. The higher the LO power, the more negative the suppression becomes.

If one assumes the maximum RF power for full system performance is +10 dBm and the LO power level is +20 dBm, then ΔP = -10 dB minimum. Therefore in this example, the 3RF-2LO mixing product would be 2ΔP - 44 = - 20 - 44 = -64 dB when

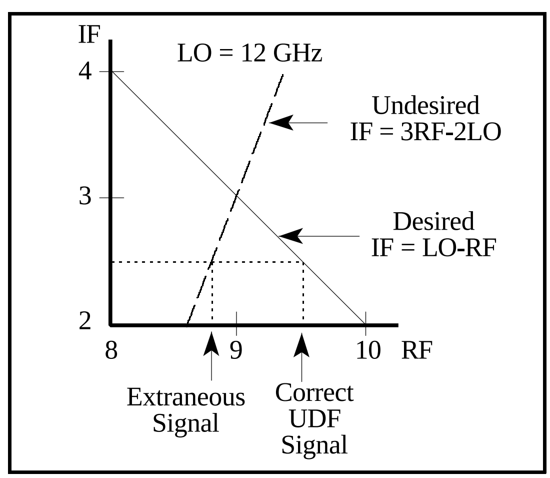

Figure 7. High Side Mixing Byproducts

compared to the desired mixing product.

The use of double mixing, as shown in Figure 8, can significantly reduce unwanted signals but it is more expensive. For a 8 GHz signal in, one still generates a 2 GHz IF but by mixing up, then down, unwanted signals are not generated or significantly suppressed.

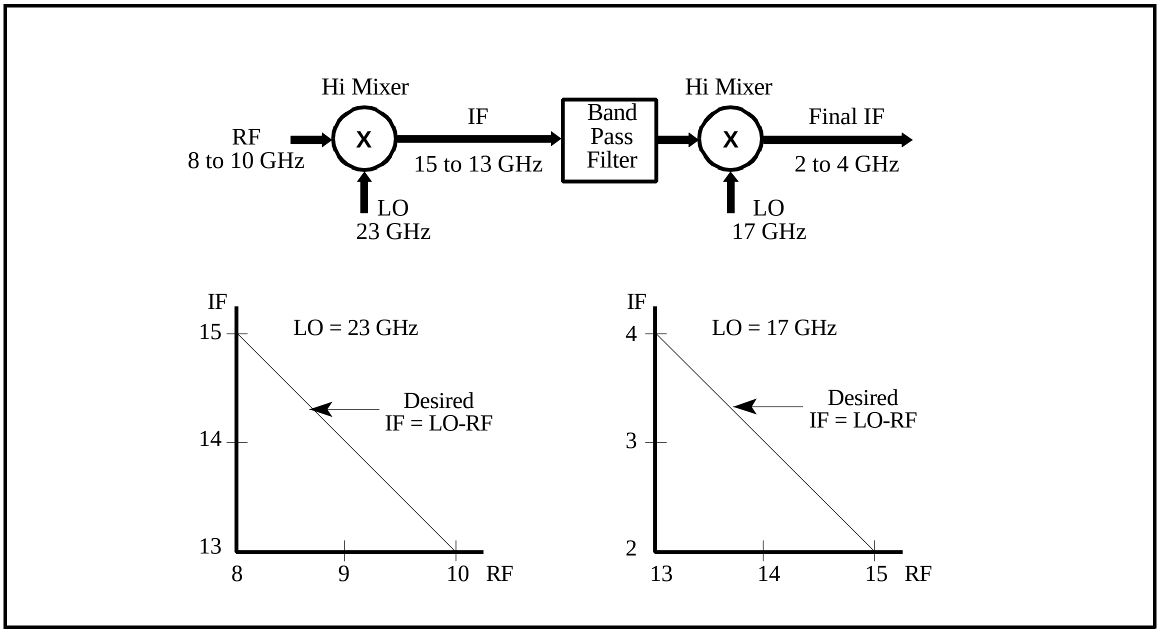

Figure 8. Double Mixing

Some of these problems can be corrected by :

(1) always having LOs on the high side versus low side of the input RF (but this is more expensive),

(2) using double mixing

(3) software programming the receiver to measure for the potential stronger signal when a weak signal is measured in a certain IF region, and

(4) improved filtering of the LO input to the mixer and the output from the mixer.

EXAMPLE 3

If the same receiver discussed in example 2 had additional bands (Figure 9) and used a switch at the IF to select individual bands, a strong signal in an adjacent band could be inadvertently measured because:

(1) the switch, which may have 80 dB of isolation when measured outside the circuit, may only have 35 dB isolation when installed in a circuit because of the close proximity of input and output lines,

(2) the strong signal in one band may have the same IF value that is being sought in an adjacent band, and

(3) the additional parameters such as PRI may be the same.

As shown in Figure 9, assume that in band 2 we are looking for a 4.5 GHz signal that has a PRI of 1 kHz. Measurements are made at an IF of 3.5 GHz since LO-RF = IF = 8-4.5 = 3.5 GHz. If a 6.5 GHz signal is applied to band 3, its IF also equals 3.5 since LO-RF = 10-6.5 = 3.5 GHz. If this is a strong signal, has a PRI of 1 kHz, and there is switch leakage, a weak signal will be measured and processed when the switch is pointed to band 2. The receiver measures an IF of 3.5 GHz and since the switch is pointed to band 2, it scales the measured IF using the LO of band 2 i.e., LO-IF = RF = 8-3.5 = 4.5 GHz. Therefore, a 4.5 GHz signal is assumed to be measured when a 6.5 GHz signal is applied. Similarly this 6.5 GHz signal would appear as a weak 3.5 GHz signal from band 1 or a 9.5 GHz signal from band 4.

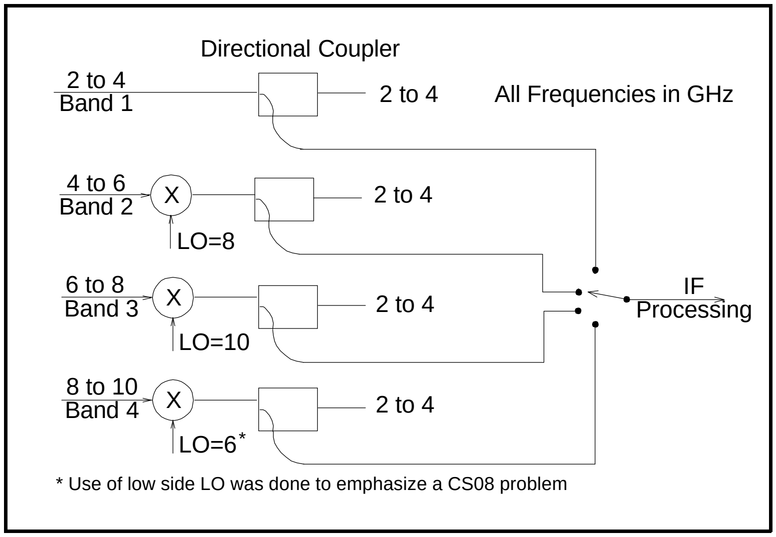

Figure 9. Multi Band Receiver with Common IF

In performing this test it is important to map the entries of the UDF for each band i.e., show each resulting IF, its PRI, and the sensitivity level that the receive light is supposed to illuminate, i.e., if a test in one band used a PRI corresponding to a PRI in another band where the receive threshold is programmed to not be sensitive this will negate the effectiveness of a cross coupling test. Mapping the UDF will facilitate applying a strong signal to one band using the PRI of a desired signal in an adjacent band.

CS08 TEST PROCEDURE

Assume that the receiver band is 2 to 4 GHz as shown in Figure 10. Pick the UDF entry that has the greatest sensitivity. UDF #1 entry is for a 3±.05 GHz signal with a PRI of 1 kHz. If the test signal is set for the UDF #1 PRI, a receive light will also occur at the frequencies of UDF #2 if it also has the same PRI (this is not a test failure). If adjacent bands don't also have entries with the same PRI, then the test should be repeated for the band being tested with at least one of the adjacent band PRI values.

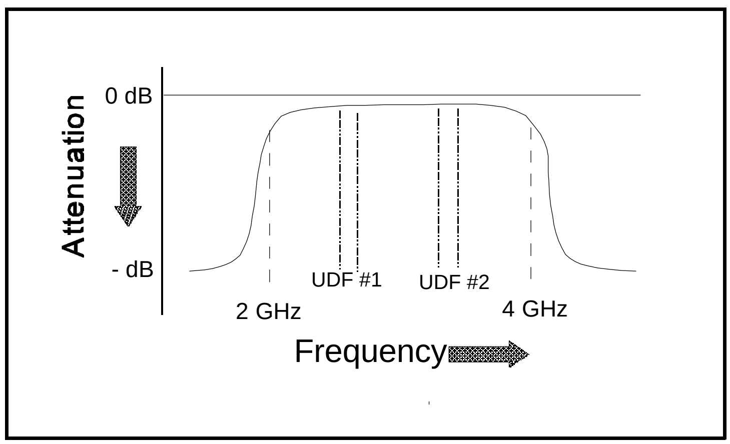

Figure 10. Receiver Band with Multiple UDF Entries

(1) Set the receiver or jammer to the receive mode, verify it is working for UDF #1 and record P_o, the minimum signal level where the receive light is constantly on.

(2) Raise this signal to its maximum specified level for full system performance. If a maximum level is not specified, use +10 dBm peak for a pulse signal or -10 dBm for a CW signal.

(3) Tune this strong RF signal outside the UDF #1 range and record any RF frequency where the receive light comes on. If another inband UDF has the same PRI, this is not a failure.

(4) This test is performed both inband and out of band. Out of band tests should be performed on the high end to five times the maximum inband frequency or 20 GHz, whichever is less, and on the low end to IF/5 or 0.05 F_0, whichever is less, unless otherwise specified. The out of band power level is +10 dBm peak for a pulse signal or -10 dBm for a CW signal, unless otherwise specified.

(5) If a receive light comes on when it is not supposed to, record the RF and reduce the power level to where the receive light just stays on constantly. Record this level P_1. The interference rejection level is P_1-P_0= P_{IR}

(6) Repeat this test for each type of signal the receiver is supposed to process, i.e. pulse, PD, CW, etc.

CS04 - DESIRED WITH UNDESIRED, TWO SIGNAL INTERFERENCE TEST

The intent is for a weak desired signal to be received in the presence of an adjacent CW signal. The desired signal is kept tuned at minimal power level and a strong unmodulated signal is tuned outside the UDF region. Radar and EW receivers without preselectors are likely to experience interference when this test is performed inband. Receivers with nonlinear devices before their passive band pass filter, or filters that degrade out of band, are likely to experience susceptibility problems when this test is performed out of band.

Tests performed inband - An unmodulated CW signal is used. If the receiver is supposed to handle both pulsed and CW signals, this test is performed inband. If the pulse receiver is supposed to desensitize in order to only process pulse signals above the CW level, then only this limited function is tested inband i.e., normally the levels correspond, if a CW signal of -20 dBm is present, then the receiver should process pulse signals greater than -20 dBm.

CS04 TEST PROCEDURE

(1) As shown in Figure 11, initially the pulse signal is tuned to F_0 and the minimum receive level P_0 is recorded, i.e., minimum level where the receive light is constantly on.

(2) The pulse signal is raised to the maximum specified level for full system performance and tuned on either side of F_0 to find the frequencies on both sides (F_{High} and F_{Low}) where the receive light goes out. If a maximum pulse power level is not specified, then +10 dBm peak is used.

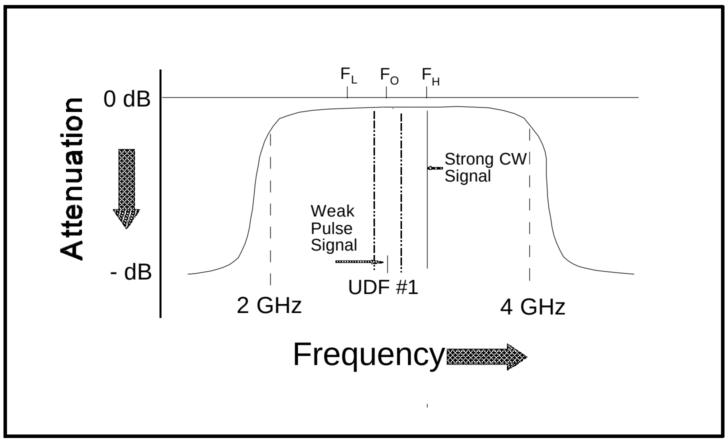

Figure 11. CS04 Test Signals

In some receivers F_L and F_H are the band skirts.

(3) The pulse signal is returned to the level found in step 1. A CW signal at the maximum specified CW power level for full system performance is tuned above F_H and below F_L. If a maximum CW power level is not specified, then -10 dBm is used. Anytime the receive light is lost, the tuned CW RF value is recorded. The CW signal should be turned off to verify that the pulse signal can still be received in the absence of interference. If the pulse signal is still being received, then the interfering CW signal should be reapplied and decreased to the lowest power level where the receive light stays on constantly. Record this level P_1. The interference rejection level is P_1 - P_0 = P_{IR}.

(4) Out of band tests should be performed to five times the maximum inband frequency or 20 GHz, whichever is less, and on the low end to IF/5 or 0.05 F_0, whichever is less, unless otherwise specified. The out of band CW power level is -10 dBm unless otherwise specified.

Failures - Out of band test

(1) If a non-linear device such as a limiter is placed before a band pass filter, a strong out of band signal can activate the limiter and cause interference with the inband signal. The solution is to place all non-linear or active devices after a passive band pass filter.

(2) Band pass filters with poor characteristics tend to pass signals with only limited attenuation at frequencies that are three times the center frequency of the band pass filter. Passage of a CW or high duty cycle signal that is out of band may desensitize or interfere with the processing of a weak inband signal.

CS03 INTERMODULATION TEST

This two signal interference test places a pulse signal far enough away (Δf) from the desired UDF frequency (F_0) that it won't be identified. A CW signal is initially placed $2\Delta f$ away. If an amplifier is operating in the saturated region, these two signals will mix and produce sum and difference signals. Subsequent mixing will result in a signal at the desired UDF frequency F_0 since $F_1 - (F_2-F_1) = F_0$. These two signals are raised equally to strong power levels. If no problem occurs, the CW signal is tuned to the upper inband limit and then tuned out of band. A similar test is performed below F_0.

CS03 TEST PROCEDURES

(1) Set the receiver or jammer to the receive mode. Verify it is working at a desired signal frequency, (F_0), and record the minimum signal level i.e., lowest level where the receive light is constantly on (record this level P_0).

(2) The modulated signal is raised to the maximum specified level for full system performance and tuned on either side of F_0 to find the frequency F_1 on both sides where the receive light goes out. If a maximum power level is not specified, +10 dBm peak is used. The difference between F_1 and F_0 is Δf as shown in Figure 12.

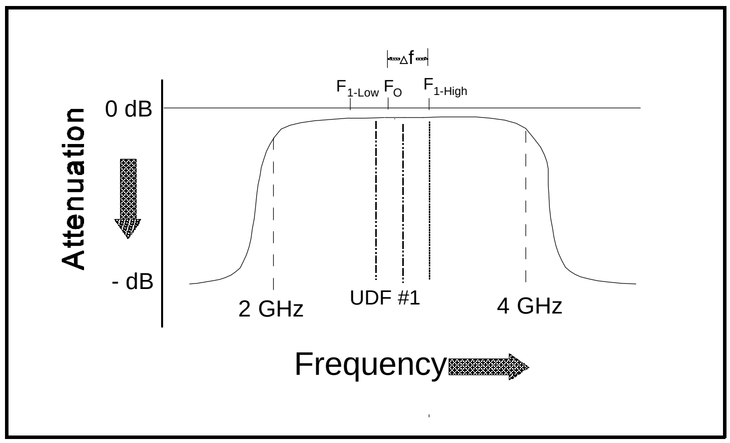

Figure 12. Initial CS03 Test Signal

(3) As shown in Figure 13, a pulse signal is tuned to F_1 and a CW signal is tuned to F_2 where $F_2 = F_1 + \Delta f$ on the high side. The power level of the two signals is initially set to P_0 and raised together until the maximum specified levels for full system performance are reached. If maximum power levels are not specified, then +10 dBm peak is used for the pulse signal and -10 dBm is used for the CW signal. Whenever the receive light comes on, the two signals should be turned off individually to verify that the failure is due to a combination of the two signals versus (1) a single signal (CS08) type failure or (2) another inband UDF value has been matched. If the

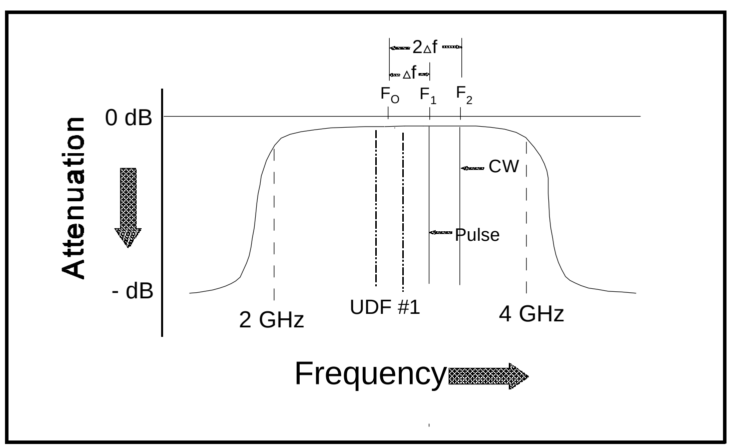

Figure 13. CS03 Testing Signal

failure is due to the two signal operation, then the power level (P_1 and P_2) of F_1 and F_2 should be recorded. If P_1=P_2, the intermodulation rejection level is P_1-P_0=P_{IM}. If $P_1 \neq P_2$, it is desirable to readjust them to be equal when the receive light just comes on.

(4) Once the F_1 + F_2 signals are raised to the maximum power test levels described in step 3 without a failure, then F_2 is tuned to the upper limit of the band. F_2 should also be tuned out of band to five times the maximum inband frequency or 20 GHz whichever is less unless otherwise specified. The out of band power level is -10 dBm unless otherwise specified. Whenever the receive light comes on, F_2 should be turned off to verify that the failure is due to a two signal test. If it is, turn F_2 back on and equally drop the power levels of F_1 and F_2 to the lowest level where the receive light just comes on. Record the power levels (P_1 and P_2).

(5) Step 3 is repeated where F_1 is Δf below F_0 and F_2=F_1-Δf. Step 4 is repeated except F_2 is tuned to the lower limit of the band. F_2 should also be tuned out of band down to 0.1 F_0, unless otherwise specified.

(6) Normally if a failure is going to occur it will occur with the initial setting of F_1 and F_2. Care must be taken when performing this test to ensure that the initial placements of F_1 and F_2 do not result in either of the signals being identified directly.

As shown in Figure 14, if F_1 was placed at 3.2 GHz it would be identified directly and if F_2 was placed at 3.4 GHz it would be identified directly. Whereas, if F_1 was at 3.1 GHz and F_2 was at 3.2 GHz neither interfering signal would be identified directly but their intermodulation may result in an improper identification at F_0. Later when F_2 is tuned higher, the receive light will come on around 3.4 GHz and 3.6 GHz. This is not a test failure just a case of another inband UDF value being matched.

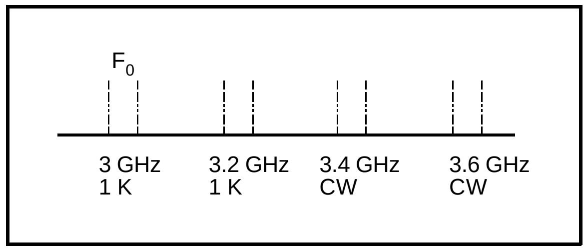

Figure 14. Sample UDF Entries

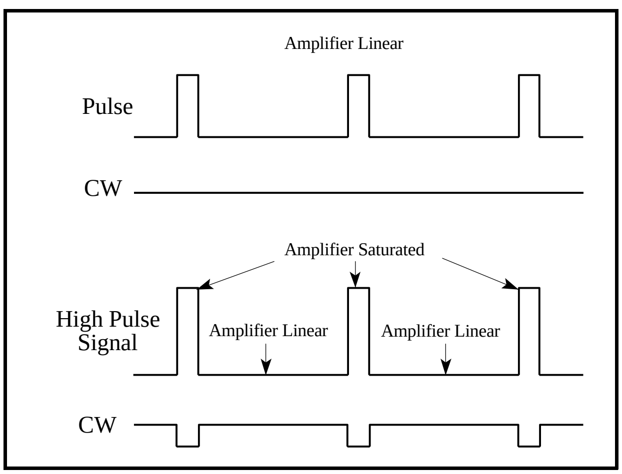

Figure 15. Cross Modulation Example

CS05 - CROSS MODULATION

This two signal interference test places a weak CW signal where the receiver is programmed for a pulse signal and tunes a strong pulse signal elsewhere. As shown in Figure 15, when an amplifier is saturated, lower level signals are suppressed. When an amplifier is operated in the linear region all signals receive the rated linear gain. In this test the pulse signal will cause the amplifier to kick in and out of saturation and modulate the weak CW signal. The receiver may measure the modulation on the CW signal and incorrectly identify it as a pulse signal.

(1) Initially the pulse signal is tuned to F_0 and the minimum power level P_0 where the receive light is constantly on is recorded.

(2) As shown in Figure 16, the signal is raised to the maximum specified level for full system performance for a pulse signal and tuned on either side of F_0 to find the frequencies on both sides, (F_{High} and F_{Low}) where the receive light goes out. If a maximum pulse power level is not specified, then +10 dBm peak is used.

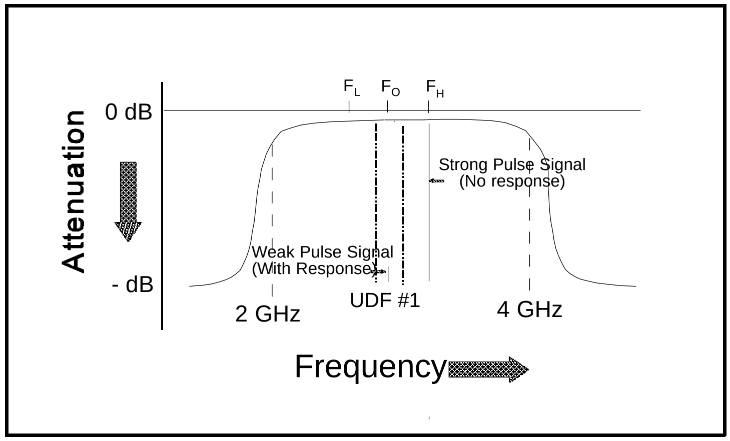

Figure 16. Initial CS05 Test Signals

(3) The pulse signal from step 2 is turned off and a second signal is placed at F_0. It is a CW signal that is 10 dB stronger than the peak power level (P_0) measured is step 1. The receive light should not come on.

(4) As shown in Figure 17, the strong pulse signal of step 2 is turned back on and tuned above F_H and then tuned below F_L. Out of band tests should be performed to the maximum RF of the system + maximum IF or 20 GHz whichever is less and on the low end to the minimum RF of the system minus the maximum IF, unless otherwise specified.

(5) If a receive light occurs, turn off the weak CW signal since the "failure" may be due to the tuned pulsed signal, i.e. a CS08 failure or another inband UDF value has been matched.

If the light extinguishes when the weak CW signal is turned off, then turn the signal back on, reduce the value of the high level pulse signal until the minimum level is reached where the light stays on constantly. Record this level as P_1. The cross modulation rejection level is P_1-P_0-10 dB = P_{CM}.

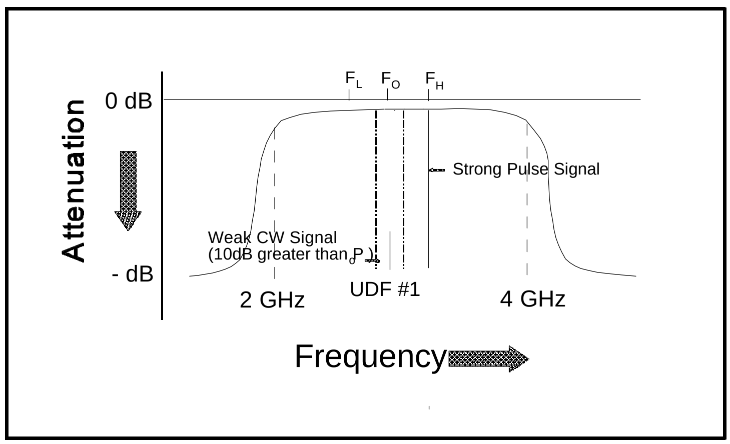

Figure 17. Final CS05 Test Signals