Application Note

PCS / AWS band PIM testing

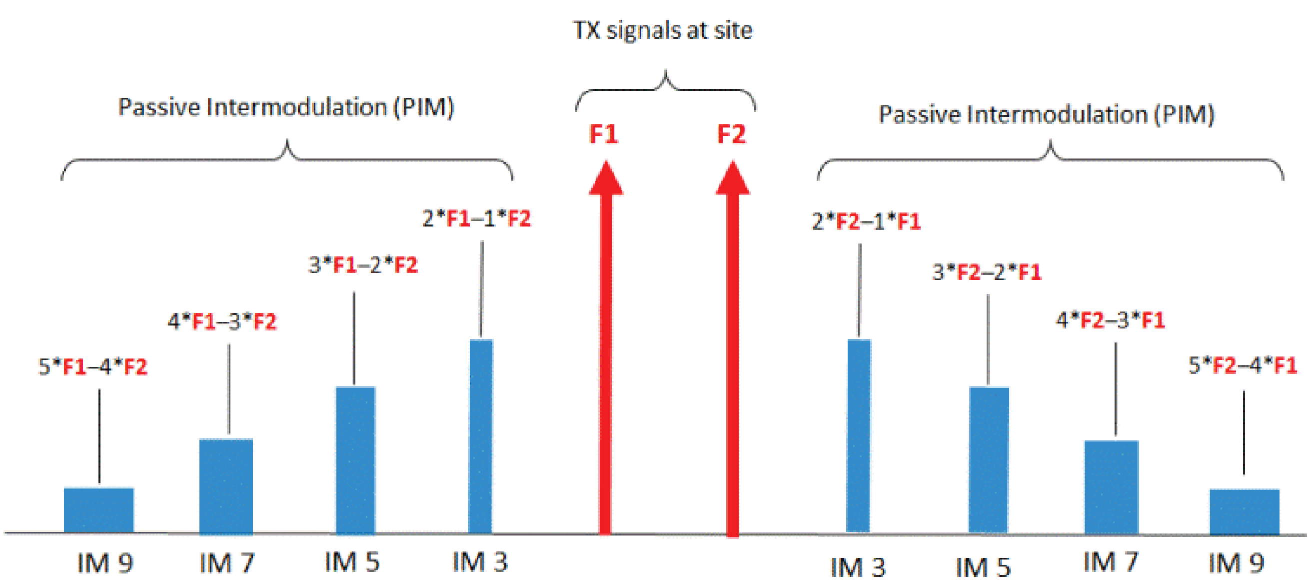
The PIM Master™ MW82119A, frequency option 193 and MW82119B, frequency option 194 are designed to support Passive Intermodulation (PIM) testing at both PCS (1900 MHz) and AWS band (1700/2100 MHz) cell sites. This application note provides a detailed summary of the PCS and AWS spectrum and provides guidance for PIM testing cell sites operating in these frequency bands.

Passive Intermodulation:

Passive intermodulation (PIM) is interference generated by the downlink signals at a cell site interacting with non-linear junctions or non-linear materials (PIM sources) in the RF path. PIM most frequently is caused by loose metal connections, lightly touching metal surfaces or corroded metal surfaces. The RF path includes not only the antenna feed system but also includes the antenna itself as well as metal objects illuminated by the antenna.

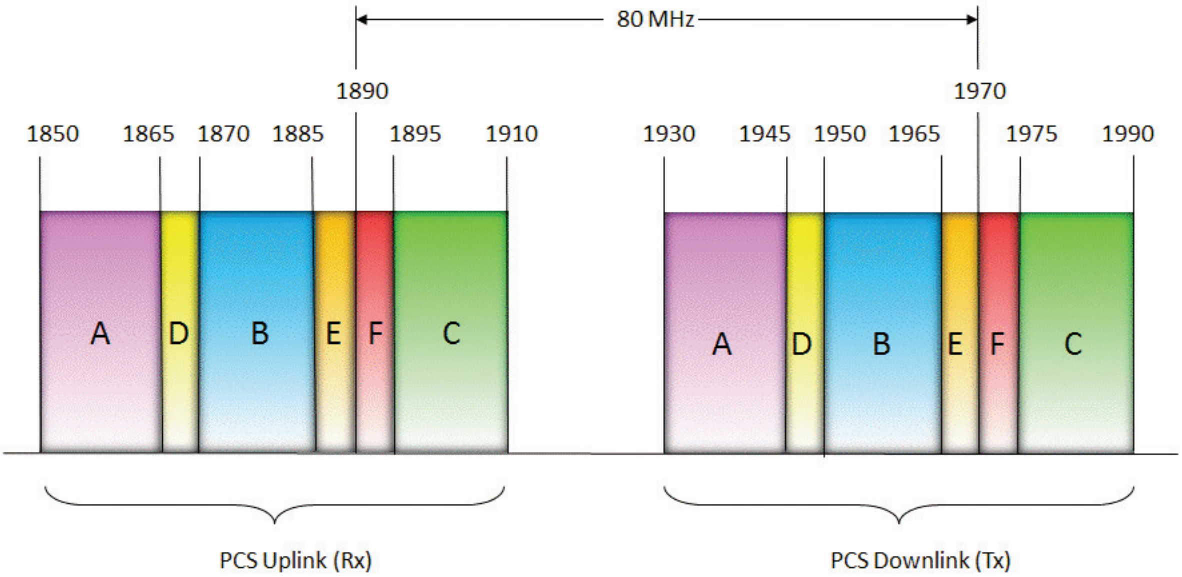
PIM sources act like a mixer, generating new frequencies that are mathematical combinations of the downlink frequencies present. PIM that fall in an operator's uplink band can elevate the noise floor, resulting in higher dropped call rates, higher access failures and lower data transmission rates.

Third order intermodulation products (IM3) fall close to the downlink frequency band are relatively high magnitude. Higher order products (IM5, IM7, IM9, etc.) fall farther away from the downlink frequencies and are successively lower in magnitude. Only in extreme circumstances (arcing, very high Tx power) will the magnitude of PIM products above IM9 be high enough to generate harmful interference in an operator's own uplink band.

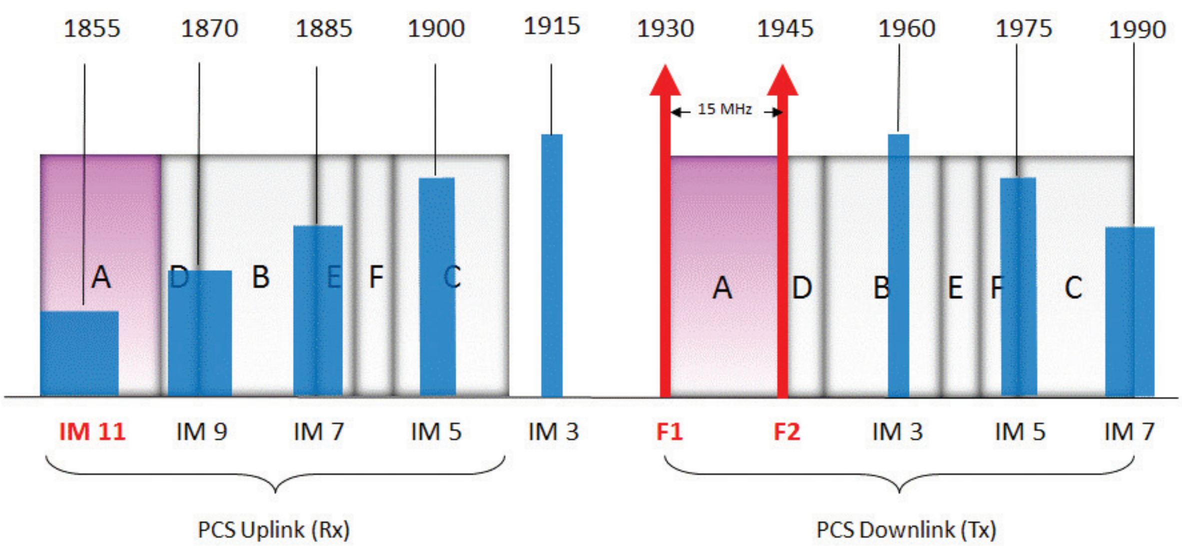


PCS spectrum:

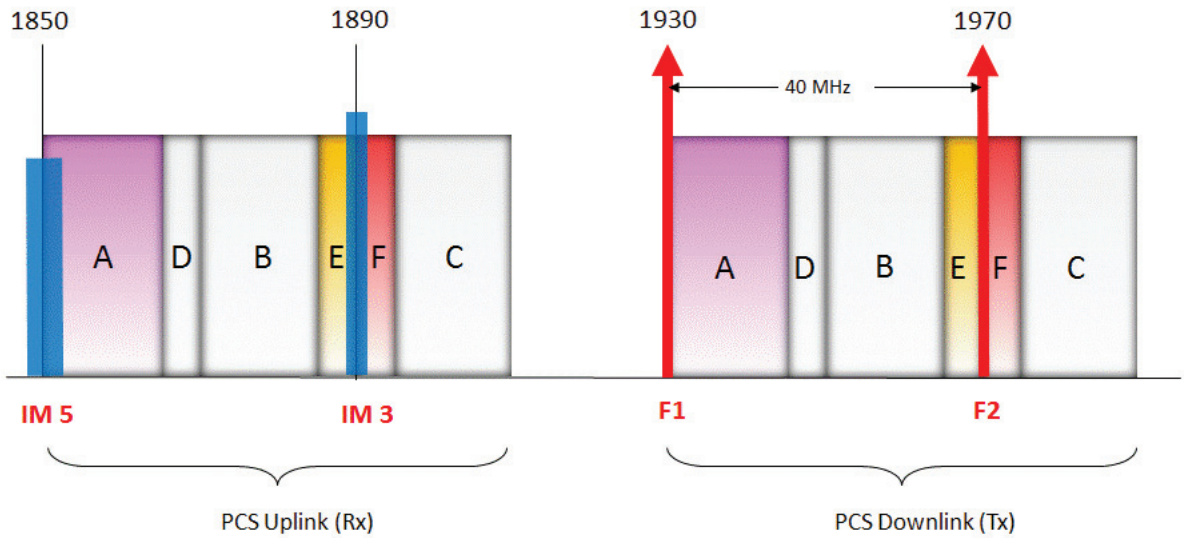
The original 1900 MHz PCS band, as defined by FCC Auctions 4, 5, and 11, consists of paired transmit and receive spectrum blocks separated by 80 MHz. Uplink frequencies (BTS receive) range from 1850-1910 MHz and downlink frequencies (BTS transmit) range from 1930-1990 MHz.



The FCC did a good job when designing the PCS spectrum in that the lowest order PIM product that can fall in a single spectrum owner's uplink band is IM11. This means that individual blocks of PCS spectrum are fairly robust against intermodulation interference. PIM sources that might cripple the performance of 700 MHz or 850 MHz systems (which allow IM3, IM5 or IM7 signals to fall in-band) may not severely impact PCS band performance.

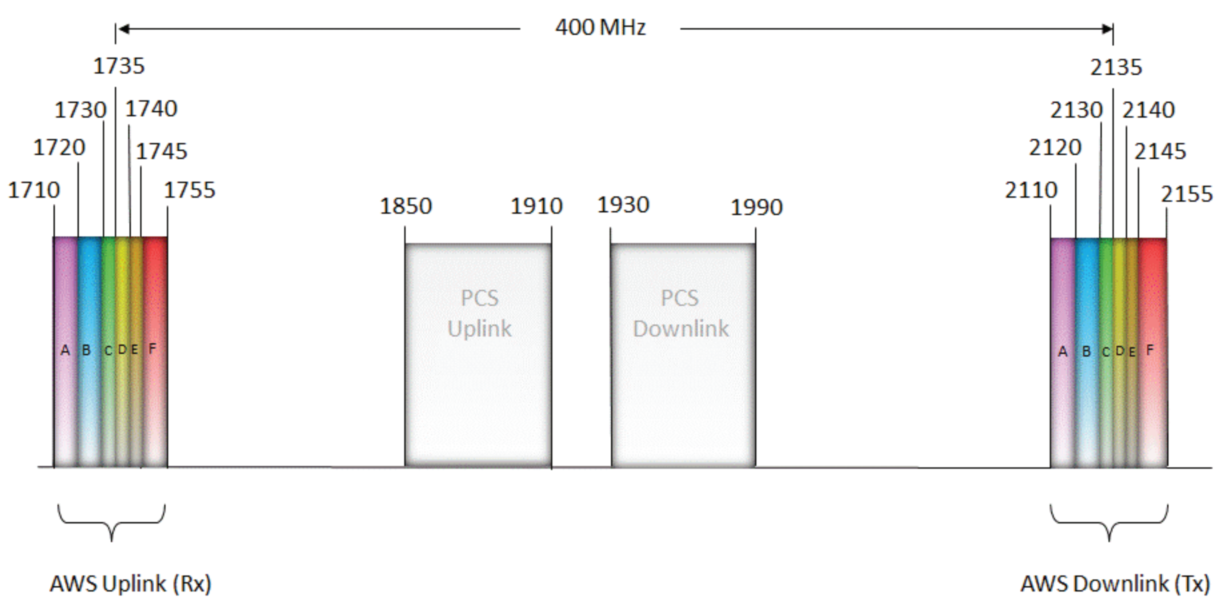


Problems can occur, however, when multiple blocks of PCS spectrum are co-located on the same antenna system. This can happen when an operator acquires additional PCS licenses in a given market or when multiple PCS operators share a neutral host DAS. In this scenario, it is not uncommon for IM3 or IM5 to fall in band and generate harmful interference for one or more PCS operators.

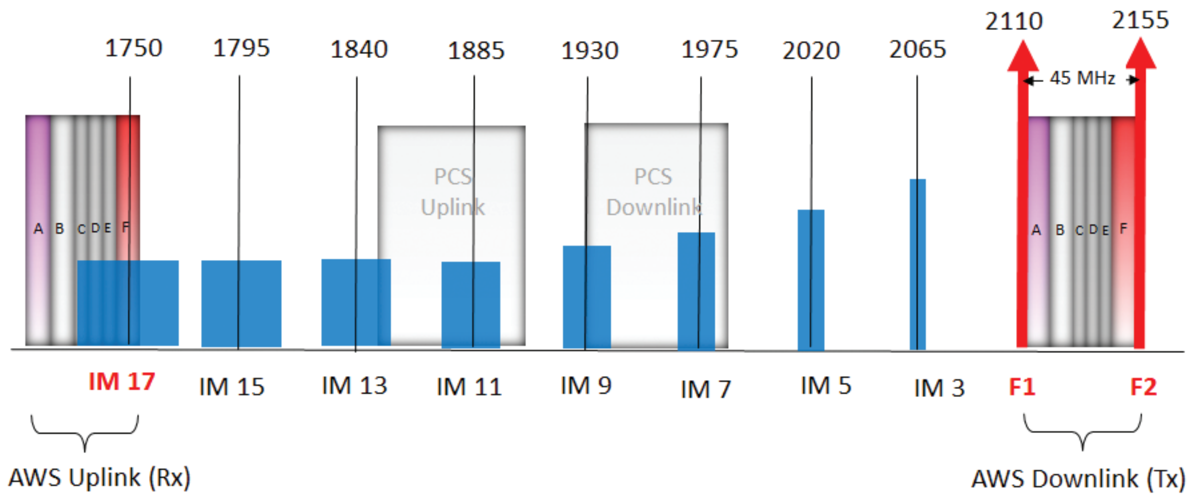


AWS spectrum:

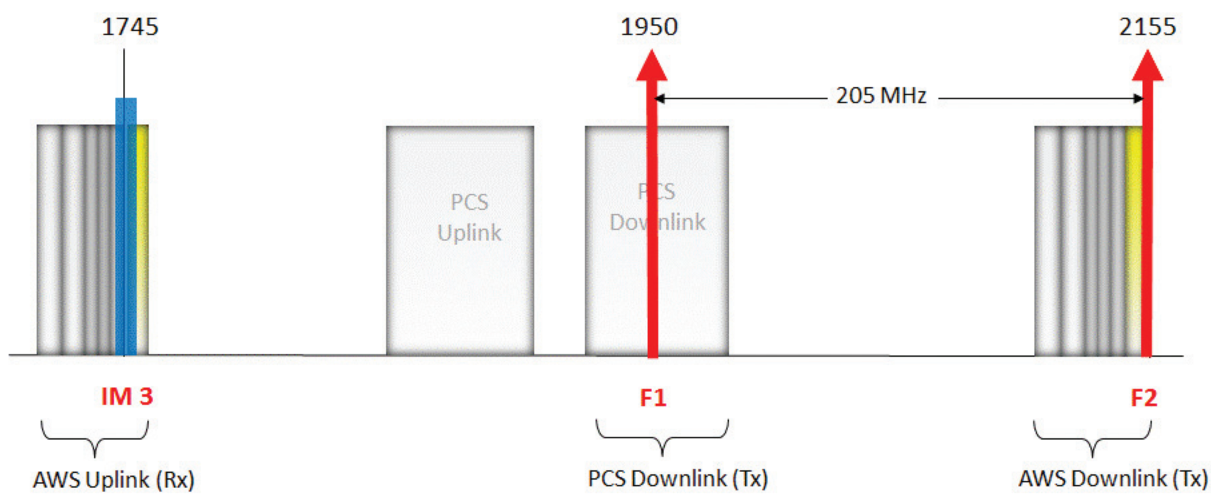
The AWS-1 band, as defined by FCC auction 66, consists of paired transmit and receive spectrum blocks separated by 400 MHz. Uplink frequencies (BTS receive) range from 1710-1755 MHz and downlink frequencies (BTS transmit) range from 2110-2155 MHz.



Due to the extremely wide separation between AWS band uplink and downlink frequencies it is highly unlikely for AWS downlink signals by themselves to generate PIM at a level that will impact system performance. The lowest order PIM product that can fall in a single AWS operator's own uplink band is IM79! Even when multiple blocks of AWS spectrum are combined together in a common feed system the lowest order PIM product that can fall in the AWS uplink band is IM17.



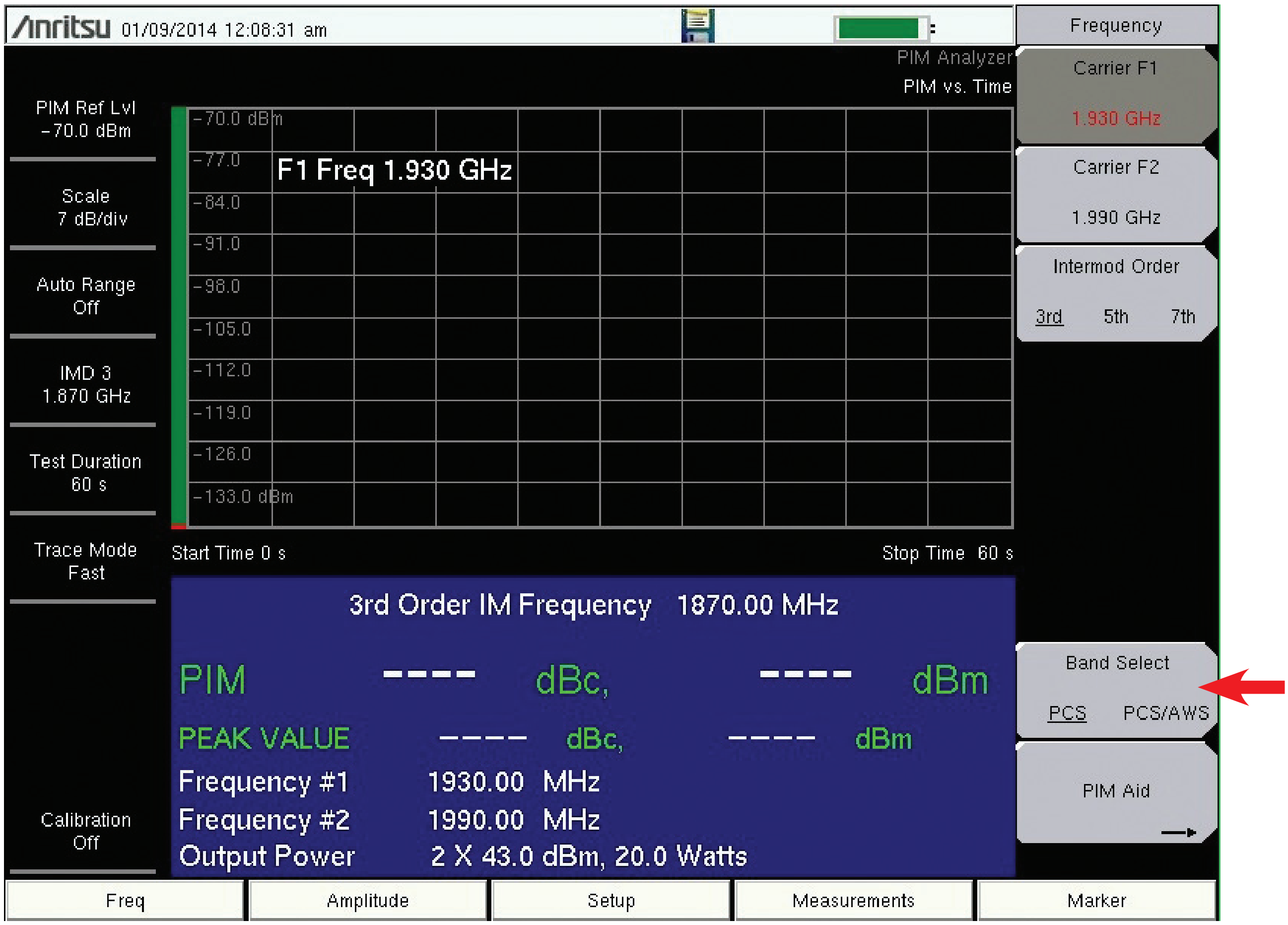
Problems can occur, however, when AWS spectrum is combined with PCS spectrum in a common feed system. In this scenario it is possible for IM3 to fall in the AWS uplink band and negatively impact site performance.



In January 2015, additional AWS spectrum became available through auction 97. This auction introduced 50 MHz of additional paired AWS spectrum (G, H, I & J blocks) and 15 MHz of additional un-paired / uplink only spectrum (A1 & B1 blocks.) This new AWS-3 spectrum increases the number of PCS + AWS frequency combinations that can generate IM3 in an operator's uplink band, making PIM testing even more important for systems that combine PCS and AWS on the same antenna or feed network.

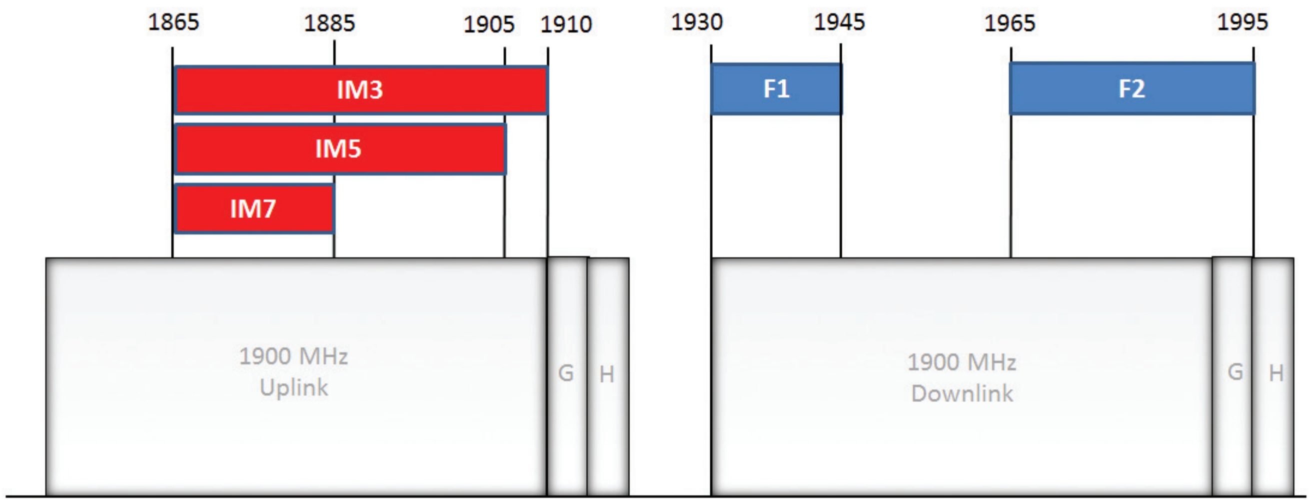
PIM Master MW82119A, Frequency Option 193:

The PIM Master™ MW82119A, frequency option 193 and MW82119B, frequency option 194 both provide the ability to test systems using two PCS test tones or using one PCS test tone combined with one AWS test tone. These two test configurations simulate the scenarios most likely to cause harmful interference to an operator. To change between PCS and PCS/AWS band testing, press the Band Select submenu key in the Frequency menu.



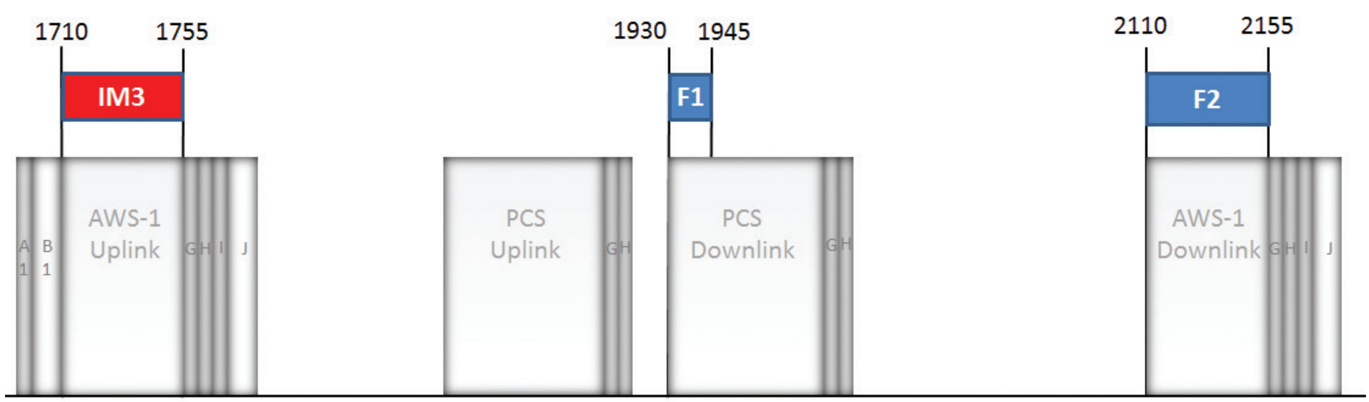
PCS band (MW82119B, Frequency Option 194):

When the PCS band is selected, the test instrument will transmit two test tones in the PCS downlink band and receive IM3, IM5 or IM7 intermodulation products that fall in the PCS uplink band. The first test frequency (F1) can be adjusted within the range of 1930-1945 MHz and the second test frequency (F2) can be adjusted within the range of 1965-1995 MHz. Intermodulation products are received in the range of 1850-1910 MHz.



PCS/AWS band (MW82119B, Frequency Option 194):

When the PCS/AWS band is selected, the test instrument transmits one test tone in the PCS downlink band and the second test tone in the AWS-1 downlink band. Third order intermodulation products (IM3) are measured in the AWS-1 uplink band.



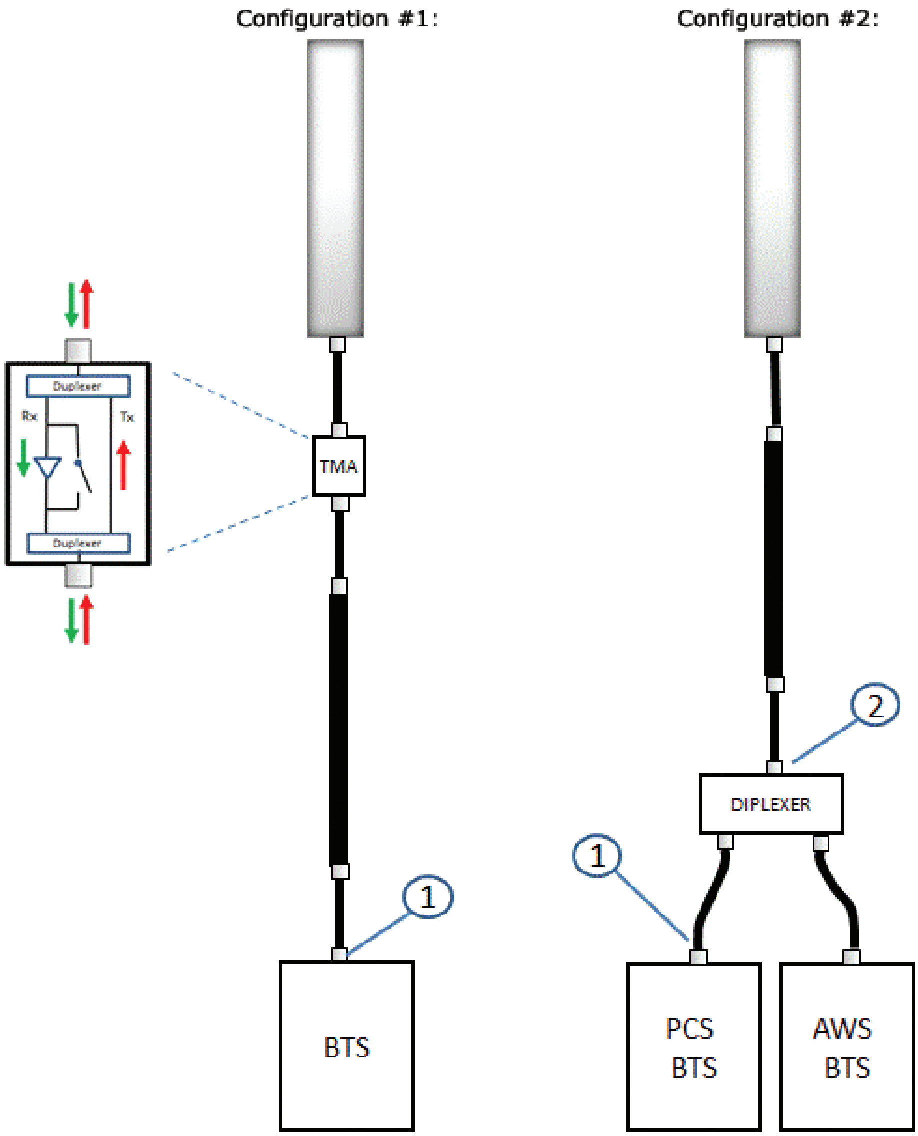
Which frequency ban should you use?

PIM sources are inherently broad band and will generate PIM whether tests are conducted using two PCS tones or one PCS and one AWS test tone. The exact magnitude of the PIM generated will vary as the test frequencies are changed. The data below gives an indication of how much the magnitude changes for a variety of objects tested at different test frequencies. Even with this small sample size variations in the range of ±2 dB are observed.

PIM source tested	F1 = PCS F2 = PCS IM3 = PCS	F1=PCS F2= AWS IM3 = AWS	Difference
PIM standard #1	–78.8 dBm	–77.0 dBm	+1.8 dB
PIM standard #2	–79.8 dBm	–79.7 dBm	+0.1 dB
PIM standard #3	–98.9 dBm	–98.4 dBm	+0.5 dB
Low PIM Load	–121.6 dBm	–122.3 dBm	–0.7 dB
Jumper Cable #1	–103.6 dBm	–103.0 dBm	+0.6 dB
Jumper Cable #2	–79.0 dBm	–81.0 dBm	–2.0 dB
Antenna	–69.0 dBm	–69.0 dBm	0.0 dB

In order to achieve the most accurate measure of a system's linearity it is preferred to perform PIM tests using frequencies close to those actually in operation at the site. So, for a PCS site it is preferred to use two PCS test tones. For a site combining PCS and AWS into a common feed system, it is preferred to use a combination of PCS and AWS test tones.

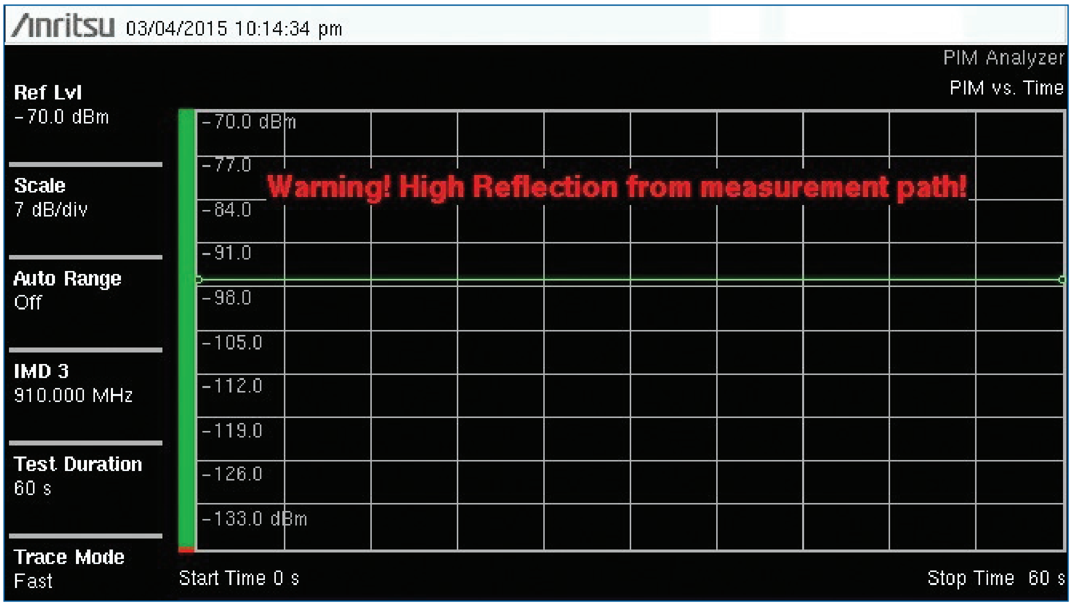
There are some practical limitations, however, that should to be taken into consideration when deciding which test frequencies to use. Frequency limiting components such as TMA's and diplexers limit where in a system the test equipment can be used. The following examples illustrate this point.



Site configuration #1 shows a single band system with a Tower Mounted Amplifier (TMA) installed at the top of the tower. If this were a PCS band system two PCS test tones could be injected at point #1 to fully test this site. The two PCS band test tones (F1, F2) are able to pass completely through the system and out the antenna. Any PIM generated along the path can pass directly back to the test set for analysis.

If this were an AWS band system, it could not be fully tested using PCS or PCS/AWS test tones without first by-passing the TMA with a short jumper cable. Duplexing filters inside the AWS band TMA typically block PCS signals, making it impossible for the PCS test tone to make it beyond the TMA. Due to the very low probability that AWS band systems will generate service effecting PIM, it is not required to PIM test AWS-only systems for the sake of interference mitigation. If PIM testing for quality control, by-pass the TMA with a short jumper cable and perform the PIM test using either test set.

The PIM Master continuously monitors reflected power at the F1 and F2 test frequencies. If high reflected power is detected on either test frequency a warning message appears on the instrument display and the test is terminated. This not only protects the test instrument, but also informs the user that something is blocking the test signals in the RF path. To analyze the problem first perform a return loss sweep over the 1930 to 2155 MHz frequency band. Return loss should be >10 dB over the F1 and F2 frequency ranges for a successful PIM test. Use Distance-to-Fault (DTF) to determine the location of the blockage and perform the necessary repairs. In the case of a narrow band filter or narrow band TMA, “repair” will involve by-passing that device with a short, low PIM jumper cable.



Site configuration #2 shows a dual band system combining PCS and AWS at the bottom of the tower, sharing a common antenna and common feed system. Two PCS test tones could be injected at point #1 and once again pass both test tones completely through the system, measuring IM3 generated along the full RF path. If a combination of PCS and AWS test tones is used, it would have to be injected at point #2 since one tone would be blocked by the diplexer if injected at either the PCS or AWS inputs. In this case, testing with two PCS test tones does a more thorough job of testing the site since the test tones are able to pass through the diplexer to verify all components in the RF path.

As presented before, harmful PIM interference is only possible in an AWS band system where AWS downlink signals are able to mix with PCS downlink signals. By PIM testing the PCS RF path with two PCS test tones, we are able to find and eliminate all PIM sources where PCS and AWS could mix.

Conclusion:

If you are a contractor performing PIM test for an operator, follow that operator’s required procedure using the test frequencies specified. Before testing, identify all frequency limiting components in the system and by-pass as required to insure both F1 and F2 are able to fully pass through the system and that the IM product frequency is able to make it back to the test set.

If test frequencies are not specified by the operator, it is recommended that you test using two PCS test tones to verify PIM performance. As can be seen in the above examples, PCS test tones are able to test more site configurations without by-passing components and are able to test all locations in the RF path where PCS and AWS signals are able to mix to generate harmful interference.

NOTES

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