VARIANCES TO EQUIPMENT AND TEST METHODS

Depends on the availability of test equipment, both setup and test methods may need to be reconfigured and modified. Replacement equipment must be selected carefully to avoid generating any unwanted IMD or reducing dynamic range of the setup.

LIST OF EQUIPMENT

The IMD setup is formed by two groups of test equipment – Broadband Equipment and Narrowband Equipment. Unless otherwise specified, the impedance of all equipment should be matched to 50 ohms. The following **calibrated** test equipment or equivalent shall be used to perform the IMD test specified by this application note:

Broadband Equipment

Test Equipment	**Operating Frequency**	**Manufacturer** (for reference)	**Model Number** (for reference)
Low Noise Signal Generator	10 kHz to 3 GHz	Marconi	2041
Power Meter	100 kHz to 50 GHz (depends on sensor)	Hewlett Packard	436A
Power Sensor	0.05 to 18 GHz	Hewlett Packard	8481A
Spectrum Analyzer	9 kHz to 6.5 GHz	Hewlett Packard	8595E
(1200W Power Supply – to power up power amplifiers)	N/A	Kepco	RKE 24-50K
5W Termination	DC to 3 GHz	MECA	405-1
100W Low IMD Termination	DC to 4 GHz	Bird	100-ST-MN
2W Attenuator	DC to 6 GHz	MECA	605-**10**-1 (for 10dB)
30dB Directional Coupler	700 to 2700 MHz	Microlab/FXR	CK-39N
3dB Hybrid Coupler	380 to 2500 MHz	Microlab/FXR	CA-14N
Low Loss Test Cable	3 GHz Minimum	Suitable low loss, low VSWR, shielded, flexible, coaxial cable	Various
Low VSWR Test Adapters	3 GHz Minimum	Suitable high quality, low VSWR adapters	Various
Microstrip Test Fixture Assembly	TBD	Custom Built	TBD

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Narrowband Equipment

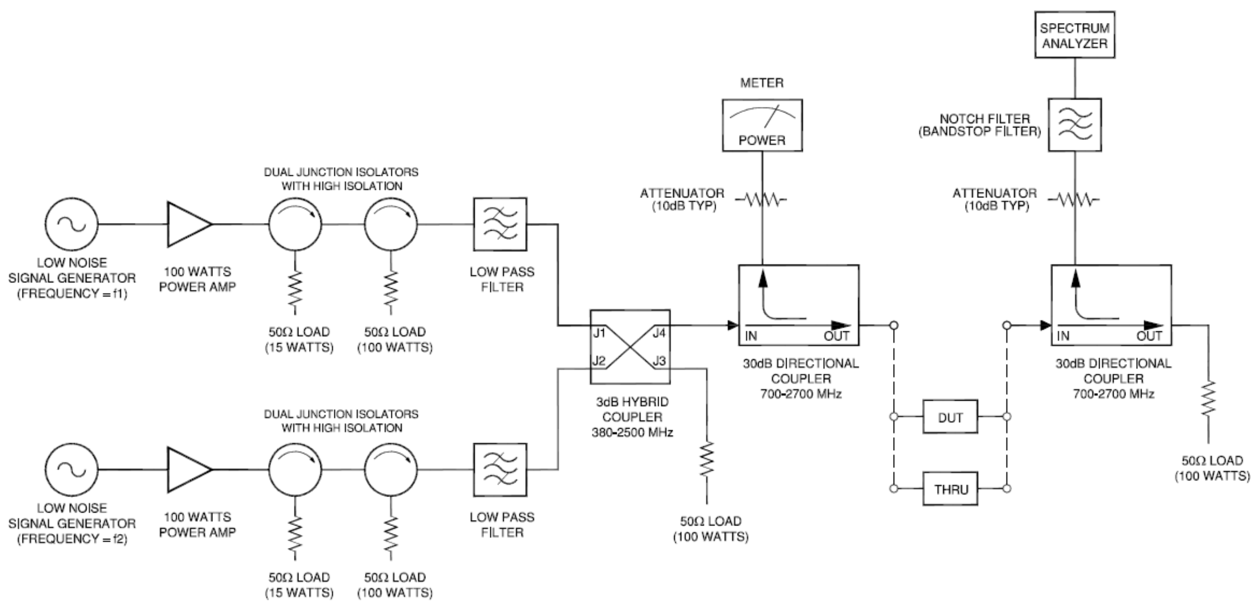
Test Equipment	Operating Frequency	Manufacturer (for reference)	Model Number (for reference)
Power Amplifiers, 50dB Gain, 100W, Narrow Band	Various	Broadband Wireless	Various
Coaxial 3-Port Circulator	Various	RFCI	Various
Low Pass Filter, High Power	Various	Microlab/FXR	Various
Tunable Notch Filter	Various	Wainwright Instruments GmbH	Various

The broadband equipment listed for reference can be used to test isolators and circulators operating from 700 MHz to 2500 MHz the narrowband equipment listed for reference can only be used for specific operating frequency range.

TWO-TONE FORWARD IMD SETUP

Figure 1 shows the block diagram of the two-tone forward IMD test setup.

FIGURE 1: FORWARD IMD TEST SETUP



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TEST PROCEDURE

Operations

For more details on how to operate equipment, please follow the instructions in user's manual or operation manual from the original manufacturer. This procedure only highlights the important settings of equipment that are used in the IMD measurement.

Preparation

1 Make sure all the connectors, adapters and cables are clean and in good working conditions.

2 Check the connector interfaces and make sure they meet manufacturer's specifications.

3 Make sure all the connections are tightened properly with correct torques and there is no open-circuit in the test setup.

4 Do not substitute a high power component with a lower power replacement.

5 Power Meter and Power Sensor
CAUTION: Do not exceed the maximum input power (typically 20dBm) of the power meter and power sensor. The attenuator between the 30dB directional coupler and the power sensor shall be adjusted as necessary.

6 Signal Generators
- Set both signal generators to CW mode.
  - f1 = first tone frequency on the one signal generator and
  - f2 = second tone frequency on the other signal generator.
- Usually the center operating frequency is selected as the center frequency (½ × (f1+f2)) of the two tone frequencies because typical outputs from power amplifiers have higher gain and better gain flatness at mid-band than band edges.
- The two tone frequencies, f1 and f2, are typically 1 MHz or 5 MHz apart, depends on required specifications. Regular standard is 1 MHz tone frequency separation.

7 Spectrum Analyzer
- **CAUTION**: Excessive signal input will damage the spectrum analyzer input attenuator and input mixer. The maximum input power shown on the front panel should not be exceeded.
- For best dynamic range, set the maximum mixer level to -40dBm.
- Set center frequency to ½ × (f1+f2).
- Set span frequency to
  5 MHz for 1 MHz tone frequency separation or
  20 MHz for 5 MHz tone frequency separation.
- Typical settings for 1 MHz tone frequency separation:
  Span = 5 MHz
  RBW = 3 kHz
  VBW = 3 kHz

  Typical settings for 5 MHz tone frequency separation:

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Span = 20 MHz
RBW = 3 kHz
VBW = 3 kHz

Note: In broader span, the sweep time of the signal trace will be slowed down. Increase the sweep time to a faster speed but make sure the spectrum analyzer is still in CAL.

8 Notch Filter

- A notch filter is used to increase the dynamic range of the IMD test setup without overdriving the mixer in the spectrum analyzer and cause additional IMD in the system. Without the notch filter, system noise floor is close to low -70dB and limit the IMD measurement.
- Depending on the design of the notch filter and the span frequency, the insertion loss at the two fundamental tone frequencies can usually be tuned to -20dB to -30dB. By using the notch filter, the tone signals can be attenuated by the same amount and increase the system dynamic range by 20dB to 30dB.
- Use a network analyzer to tune the notch filter. Set center frequency and span frequency similar to that on the spectrum analyzer. (Center Frequency = ½ × (f1+f2); Span Frequency = 5 MHz or 20 MHz)
- Set four markers: M1, M2, M3 and M4, where
  M1 = frequency of lower IM3 product = 2f1-f2
  M2 = f1 == first tone frequency
  M3 = f2 = second tone frequency
  M4 = frequency of upper IM3 product = 2f2-f1
- Adjust the tuning knobs on the notch filter to maximize the attenuations at f1 and f2. Figure 2 shows sample S21 of a notch filter tuned at 2017 MHz and 2018 MHz.
- For the lower IM3 product, the attenuation of the notch filter is given by Δ [(S21 at M1)-(S21 at M3)].

  For the upper IM3 product, the attenuation of the notch filter is given by Δ [(S21 at M2)-(S21 at M4)].

  Tune the notch filter so that it has the same level of attenuation for the lower and upper IM3 products. Ideally, loss of Δ [(S21 at M1)-(S21 at M3)] = Δ [(S21 at M2)-(S21 at M4)] or as close as possible.

  Example:

  Set frequency markers at M1 = 2016 MHz
  M2 = 2017 MHz
  M3 = 2018 MHz
  M4 = 2019 MHz

  Tune filter so that S21 at M1 (2016 MHz) = -2.64dB
  S21 at M2 (2017 MHz) = -30.31dB

  S21 at M3 (2018 MHz) = -29.84dB
  S21 at M4 (2019 MHz) = -2.88dB

  Hence we have
  Attenuation of filter for lower IM3 product = -30.31-(-2.64) = -27.67dB
  Attenuation of filter for upper IM3 product = -29.84-(-2.88) = 26.96Db

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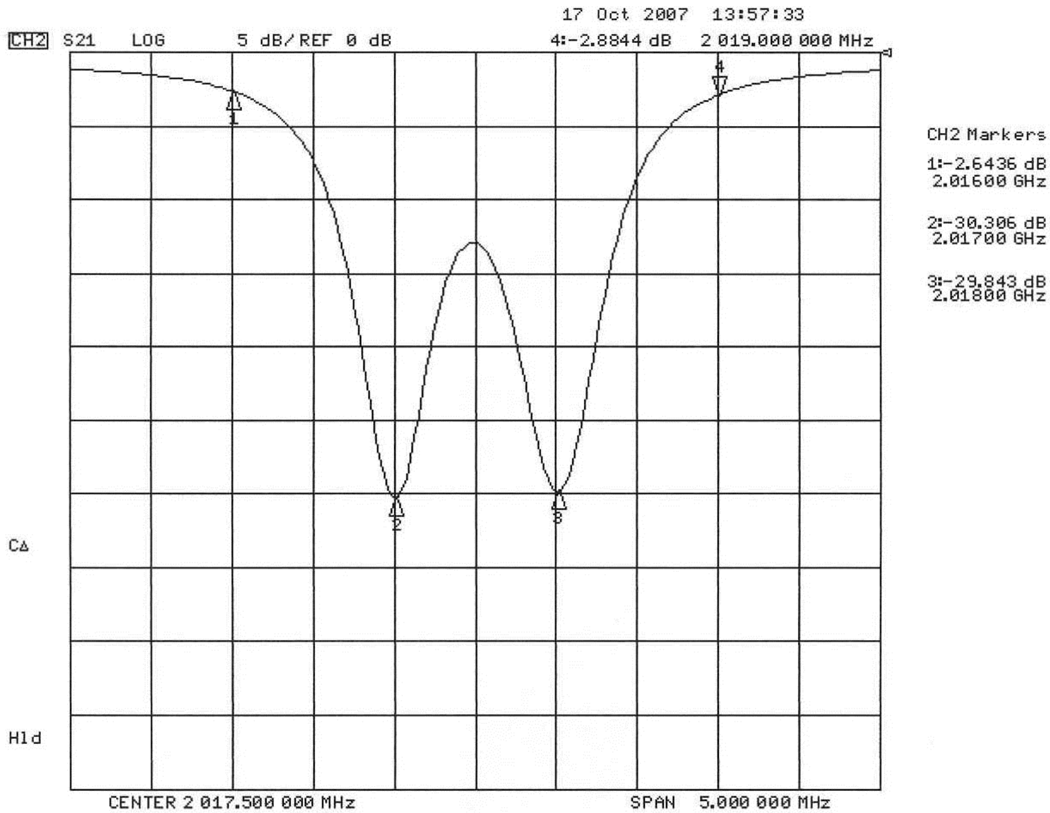

CAUTION: To prevent any injury, do not touch DUT or test fixture when the RF is turned on. Always check and make sure the RF power is OFF before replacing DUT or changing the test setup.

Calibration

Before measuring the IM3 products of DUT, we must verify that the system IMD level is at least 10dB better than the IM3 specification.

- Connect a SMA barrel (a SMA female to SMA female adapter) at the test ports.
- Make sure the RF outputs of both signal generators are OFF before turn on the power amplifiers.
- Turn on the power amplifiers and let them warm up for at least 15 minutes before making any measurement.
- Set the initial RF levels at -20dBm. Turn on RF of the first amplifier and slowly increase the RF level until the power at the test port reaches specified value. Assuming tone power for forward two-tone IMD measurement is 37.5W (45.74dBm) per tone. The power meter should read 5.74dBm after subtracting 10dB for the attenuator and 30dB for the directional coupler.

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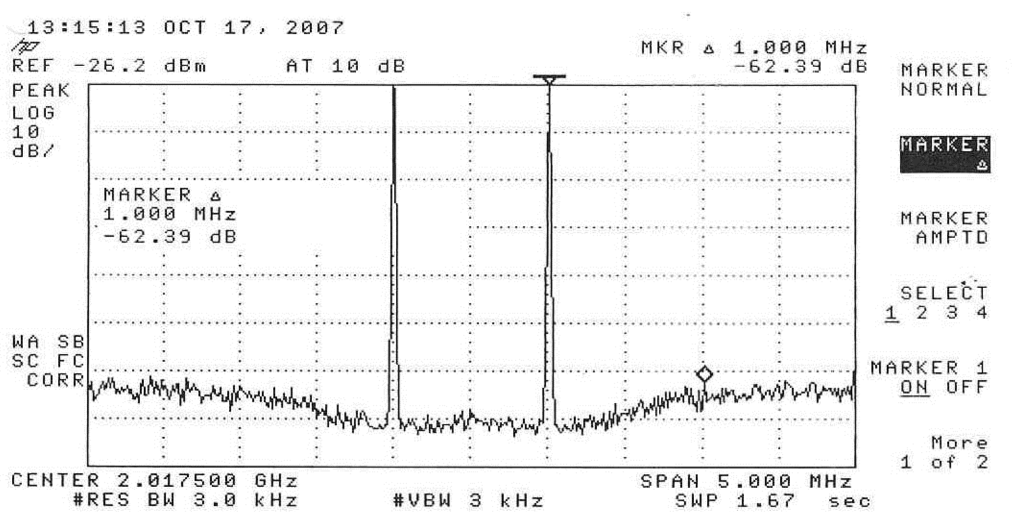
- After we set up the output RF level for the first tone frequency (f1), turn OFF the generator. Turn ON RF of the second generator and set up the output RF level for the second tone frequency (f2).

- Turn ON RF of the first generator again. The spectrum analyzer should show the two tone signals at the same power levels (45.74dBm) plus any visible distortion products.

- To measure the distortion product, press [PEAK SEARCH] to place a marker at on one of the tone signal. Use [NEXT PK RIGHT] or [NEXT PK LEFT] to select the other tone signal closer to the “worst” IM3 product. Press MARKER Δ to activate the delta marker function and place the second marker on the IM3 product. We may need to adjust the threshold value of the Spectrum Analyzer so that the IM3 product is visible above the noise floor.

- If the notch filter is tuned symmetrically and the attenuations for both upper and lower IM3 products are almost identical, the “worst” IM3 product can be determined visually. Otherwise, we have to calculate the upper and lower IM3 products by adding the attenuation of the notch filter to the two readings and compare their results.

- Here is an example plot of the IM3 product of the IMD test setup.



IM3 of Test Setup
= Δ markers (between the fundamental frequency and the upper distortion product) + (attenuation of notch filter for upper IM3)
= -62.39dB + (-26.96dB)
= -89.35dBc

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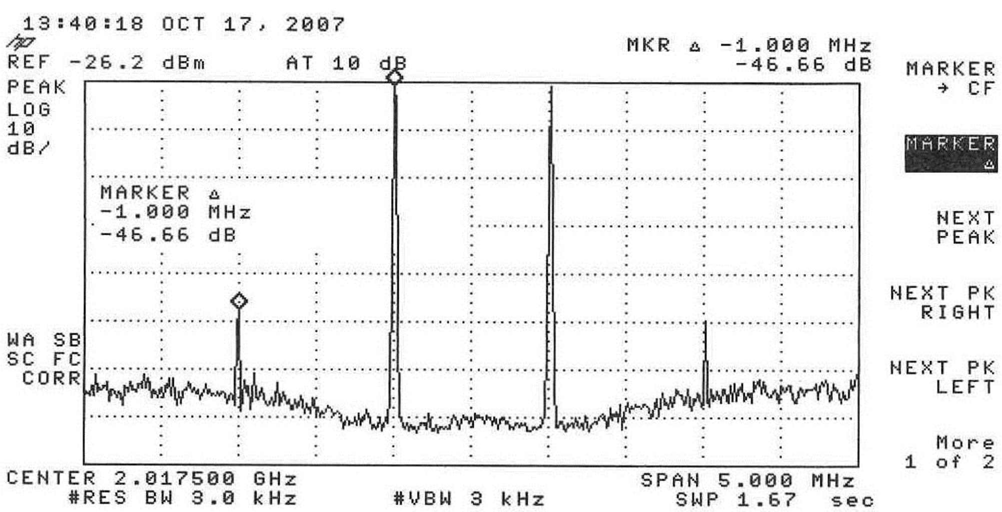
- Turn OFF RF of both signal generators after the IMD measurement.
- If the IMD test setup is not going to be used for a while, set the RF levels to the lowest levels (such as -144dBm). This prevents any possible damage to the equipment if RF of the generator is accidentally turned on.

Test DUT

- Turn OFF RF of both generators.
- **CAUTION**: Check and make sure the circuit tabs of DUT lay on top of the 50Ω line traces on the test fixture. If any one of the circuit tab does not touch the 50Ω line trace, the 50Ω line and the DUT could be damaged by the high power RF signal.
- Mount DUT on test fixtures with screws and tighten connectors with proper torques.
- Repeat steps 6.3.4 through 6.3.10 to measure the IM3 products of DUT.
- Here are the example plots of IM3 products.



Lower IM3 Product = -46.66dB + (-27.67dB) = -74.33dBc

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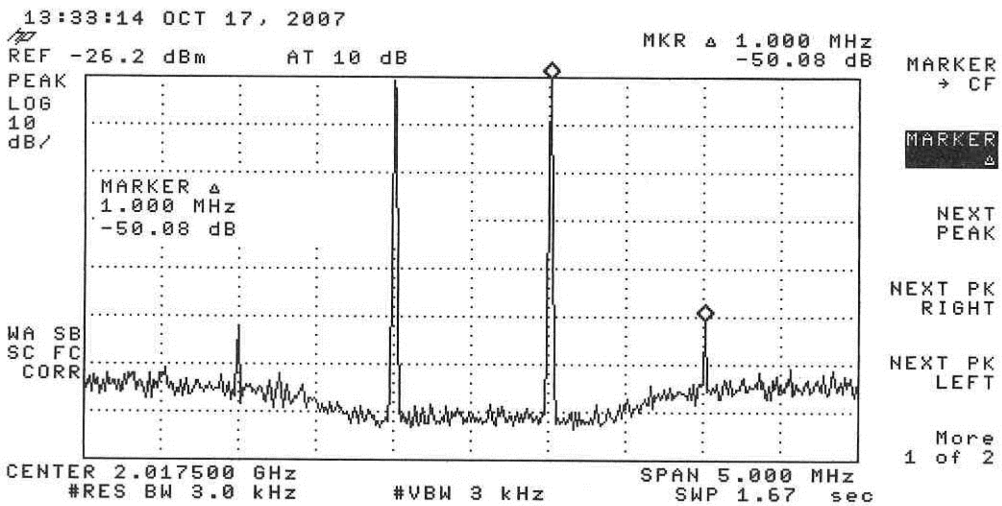

Upper IM3 Product = -50.08dB + (-26.96dB) = -77.04dBc

- Notice how the different attenuation values of the notch filter affect the IM3 products.
- Note that the IMD performance of our system is lower than what we measured for the DUT by more than 10dB therefore the impact of the system on the measurement is minimal.
- In the example plots, the lower IM3 product is worse than the upper IM3 product. Both IM3 products should meet specifications.

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