Intermodulation Distortion (IMD) Measurements of Ferrites Application Note

ANI-001
Rev A

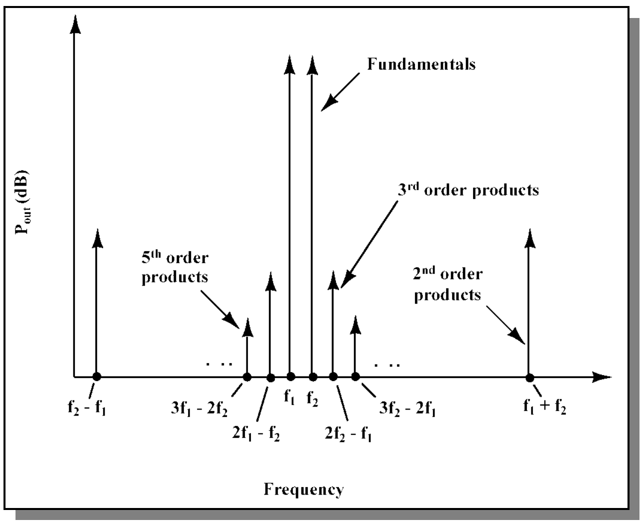
Introduction

Intermodulation Distortion (IMD) measurements are used to characterize the non-linearity of RF components, including ferrite circulators and isolators. Two CW tones (f_1 and f_2) are combined and fed into the Device Under Test (DUT). The resulting output is measured on a spectrum analyzer.

The third order, and occasionally the fifth order, products are the critical unwanted frequency IMD products that are measured.

3rd order products at: $(2 \times f_1) - f_2$ and $(2 \times f_1) - f_1$

5th order products at: $(3 \times f_1) - (2 \times f_2)$ and $(3 \times f_2) - (2 \times f_1)$



Forward IMD Test Set Up

Figure 1 is a typical block diagram of a forward IMD test stand. M/A Com uses a Agilent 83712B signal generators and Amplifier Research 100W1000M1 amplifiers. The dual isolators provide >50dB of isolation and K&L's six cavity tuneable low pass filters remove system harmonics. The M/A-Com quad hybrid (QH32-0018-N) gives a further 18dB of isolation between the tones.

The Directional Couplers (CH25-0014-10N) must be terminated with a broadband cable load with superior VSWR (<1.1:1). A six cavity notch filter (WRCD800/960 0.2/40-6EEK) attenuates the fundamental frequencies (f_1 and f_2) to provide greater dynamic range.

It is important not to overdrive the internal mixer of the Spectrum Analyzer (8561E). Overdriving the mixer can cause clipping, so the input level into the analyzer should be <-23dBm. Typical analyzer setting are:

Span = 2kHz
RBW = 3Hz
VBW = 3Hz

Cables, connectors and test fixtures can also affect the IMD measurement. N type connectors should be used, and they must be clean and torqued correctly. Avoid nickel plating. M/A-Com cables, B19X036-0-8585N, are recommended for their superior phase stability. The test fixture must enclose the DUT fully to insure adequate shielding from stray radiation.

Harmonics must be filtered before measuring power. Spectrum analyzers should be used to measure relative power only (dBc), not absolute power (dBm). Power meters are only accurate at their characteristic impedance (50 ohms), so poorly matched DUTs will introduce inaccuracies.

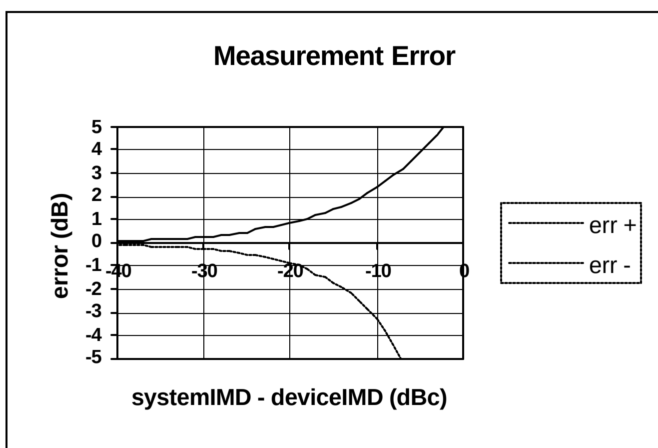
Measurement Error

There will be measurement error in every system. This measurement error can be calculated:

$$Error^{+} = 20\log\left(1+10^{(IMDsystem - IMDdevice)/20}\right)$$
$$Error^{-} = 20\log\left(1-10^{(IMDsystem - IMDdevice)/20}\right)$$

For a typical system (IMD_{system} - IMD_{device} = -15dB), the measurement error will be +1.4dB / -1.7dB.

To minimize measurement error, the IMD_{system} should be 30dB or more than the IMD_{device}.



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Phase Cancellation Reverse IMD Test Set Up
Figure 2 shows the configuration used for Reverse Intermodulation Distortion measurement with cancellation. High forward power is applied to the input of the DUT at frequency f_2 while reverse power at a lower level is applied to the output of the DUT at frequency f_1. The output signals including the IMD products are coupled through the directional coupler to the quadrature hybrid and then to the spectrum analyzer. In order to protect the spectrum analyzer input from high signal levels leading to IMD products being generated in the instrument, and thus errors in the measurement, a cancellation process is used to significantly reduce the level of the signal at f_2 without affecting the IMD products generated in the DUT. A third signal source SG3 is set to the same frequency f_2 and a signal applied to the other input of hybrid. The amplitude of the signal is adjusted to match that of the signal to be cancelled, and the phase of SG3 is then adjusted in small steps until nulling of the f_2 signal is achieved after which the phase stepping is stopped. Null depths of >40dB are routinely achieved. The levels of third order (and fifth order) IMD products can then be accurately measured in the spectrum analyzer after optimally setting resolution bandwidth, video bandwidth, attenuation, and frequency span. Cancellation of the other signal f_1 is not necessary because its level is already much lower than f_2. This technique allows the spectrum analyzer to use sensitive settings (e.g., no attenuation) with little distortion being added, with the added benefit that a lower noise floor is achieved. The system above also measures harmonics generated in the DUT. The three signal generators and the spectrum analyzer are phase locked with the signal source of one generator acting as a reference source for the other three. While operation of the system can be done manually, it is most efficiently performed by software and the entire measurement can be automated, controlling the instruments thru the GPIB ports.

Reverse IMD Test Set Up
Figure 3 is the typical block diagram of a reverse IMD test stand. This is similar to the Forward IMD test set up, except the second signal is fed into the output of the DUT.

Conclusion
Measuring Intermodulation Distortion products of a ferrite circulator or isolator can be difficult. Care must be taken that unwanted IMD products are not introduced. If you require further assistance, please contact M/A Com.

Figure 1: Forward IMD Test Set Up

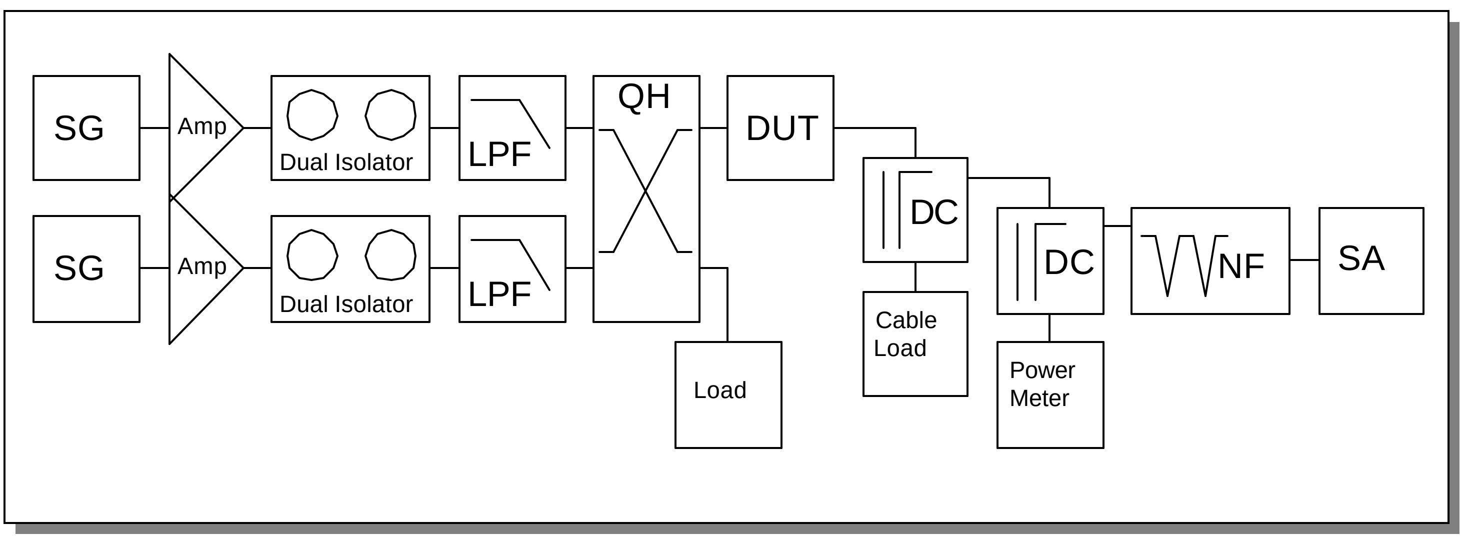

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Figure 2: Phase Cancellation Reverse IMD Test Set Up

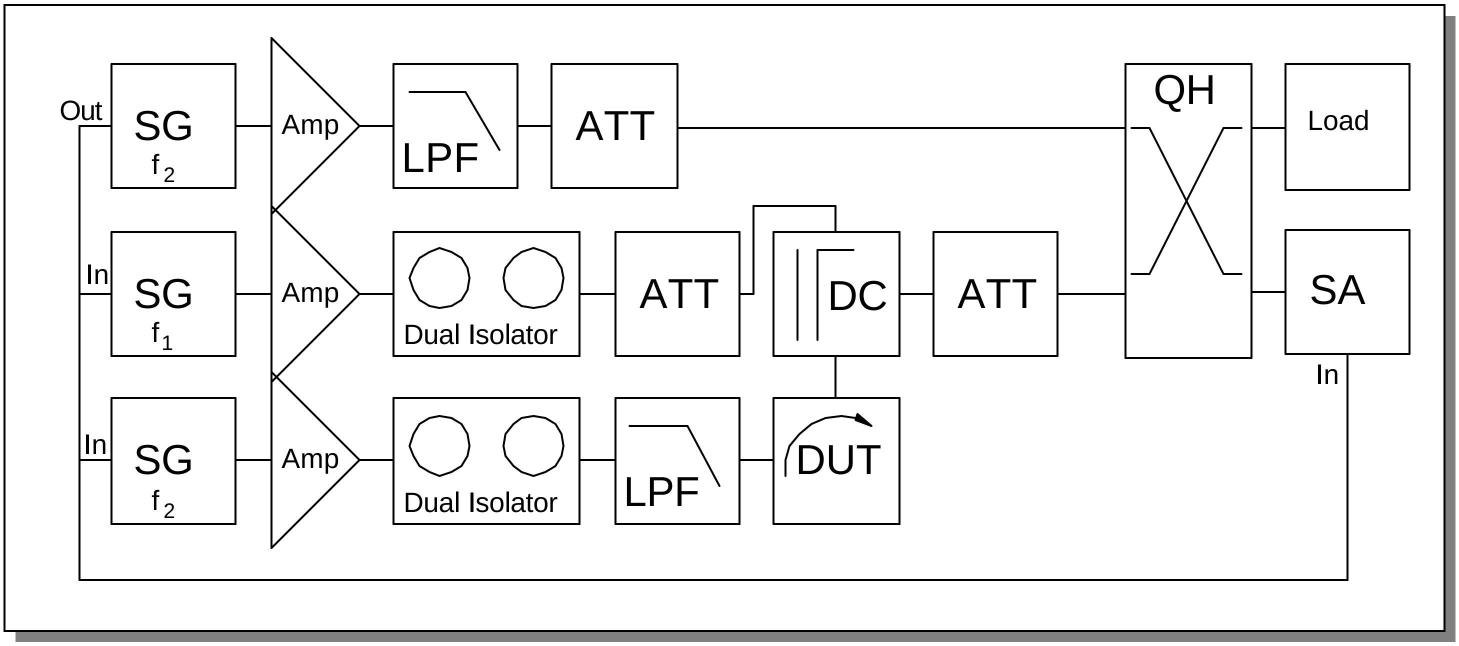
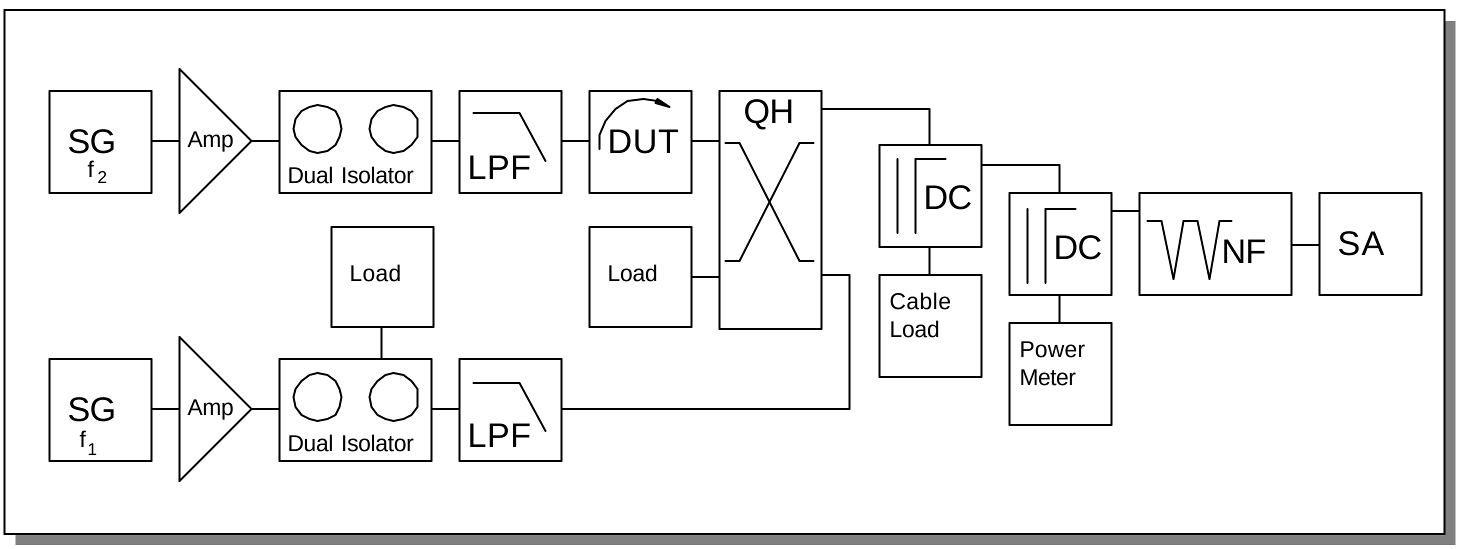


Figure 3: Reverse IMD Test Set Up



Legend:

ATT	Attenuator
SG	Signal Generator
LPF	Low Pass Filter
DUT	Device Under Tes
QH	Quad Hybrid
DC	Directional Coupler
NF	Notch Filter
SA	Spectrum Analyzer

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