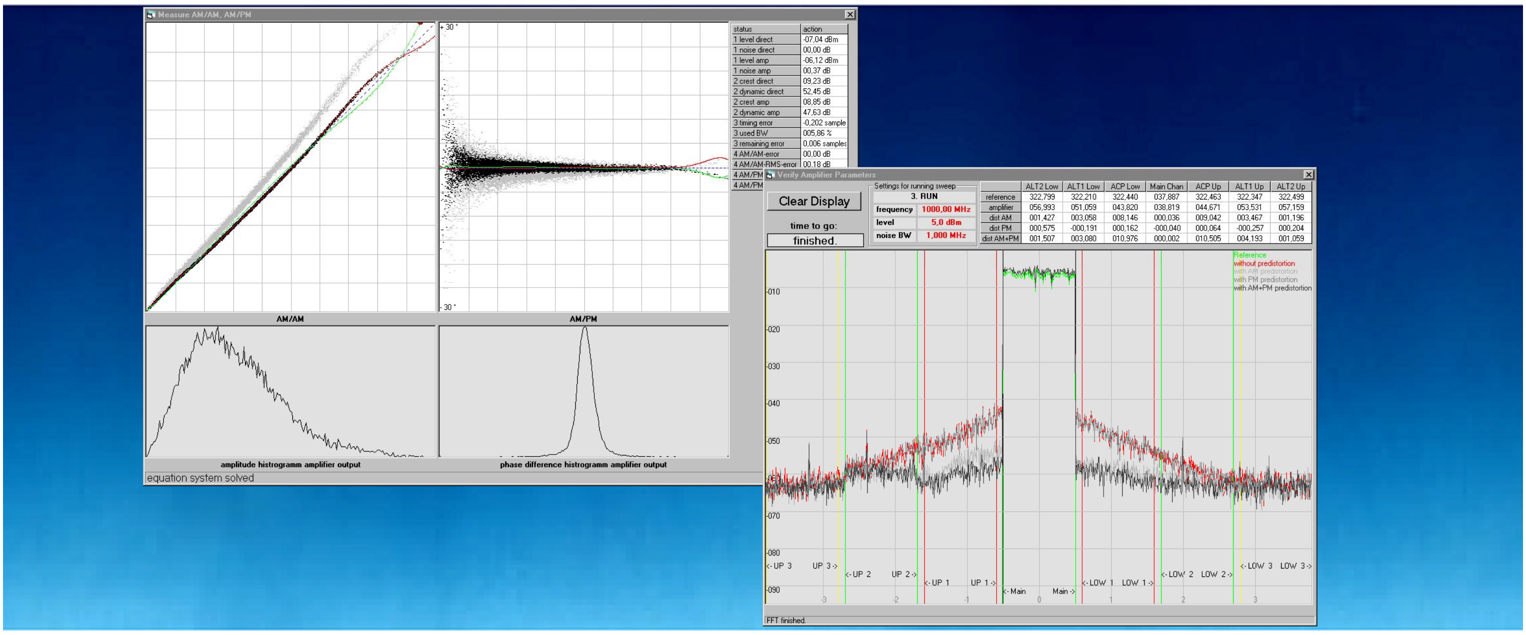


Products: AMIQ, SMIQ, FSIQ, FSP

AMPTUNE

Software for Measuring Amplifier Nonlinearity in Realistic Conditions

Application Note

With AMPTUNE amplifier nonlinearity can be measured with signals that are typical for the signals encountered by the amplifier in day-to-day use. The measurement can be checked by pre-distorting the control signal. Also, the results can be automatically stored for further processing with external programs.

ROHDE&SCHWARZ

Subject to change – M. Weiß 11.2000 – 1MA27_0E

Contents

1 Overview

If the characteristics of modern amplifiers are measured with CW signals, say with a classic network analyzer, the results – depending on the amplifier design - depend on the sweep time, the sweep direction etc. The results are, therefore, useless if characteristic compensation is the purpose of the measurement.

The method described in this Application Note (AN), and implemented as the AMPTUNE software package, measures the characteristics with a signal that would actually be used when the amplifier is in service, i.e. a W-CDMA, IS-95 or QPSK signal. The results then indicate how to pre-distort signals to compensate for the amplifier characteristics.

The test signals are generated by a signal generator with a modulation source input. After passing through the amplifier, the signal is measured, sampled and stored by a spectrum analyzer. This data is read by AMPTUNE and converted to an output amplitude vs input amplitude (AM/AM) and phase difference between input and output vs input amplitude (AM/PM) characteristic. For verification of results, the control signal can be precorrected directly via an inverse characteristic to measure the increased signal quality such as the improvement of the adjacent-channel power suppression.

2 Fundamentals

A key RF-amplifier parameter, irrespective of whether the amplifier is used for mobile radio or TV broadcasting or to handle low or high powers, is linearity. For an amplifier to be perfectly linear, the ratio of the output signal to the input signal would have be constant for any input amplitude, frequency or phase, i.e. the amplifier would have to introduce a constant gain.

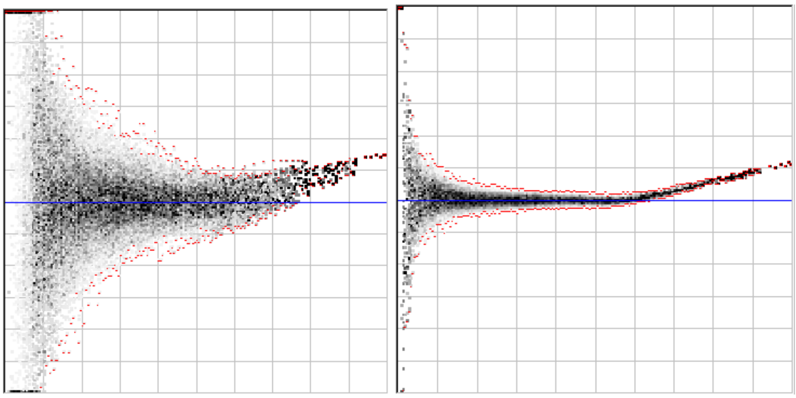
However, depending on its design, any real amplifier exhibits varying degrees of nonlinearity. The AM/AM and the AM/PM transfer characteristics are often used as measures of nonlinearity. The amplitude and phase of the input signal and the output signal are measured. The output amplitude is then plotted against the input amplitude and the difference between input phase and output phase plotted against the input amplitude.

However, these plots may not completely describe every amplifier because they can depend on the input phase or, more generally, there can be memory effects. Nevertheless, investigations have shown that AM/AM and AM/PM plots can completely describe many modern amplifiers - or at least provide a good approximation.

A 2-tone signal (= AM) is sometimes used to measure this characteristic However, the characteristics obtained in this way are not suitable for optimizing the amplifier for “real signals”, such as W-CDMA signals, because the operating point of the amplifier moves due to thermal effects and the characteristic changes considerably when a 2-tone signal is applied. This is because, a 2-tone signal has, for example, a lower crest factor than a typical modulated signal and a different amplitude distribution. The ratio between the peak and rms power is, therefore, different and the thermal stress on the amplifier different. The signal used to determine these characteristics should be as similar as possible to the signals handled by the amplifier in service. The software described in this AN employs a noise signal with settable bandwidth as standard. It is a generic signal that can be used for IS-95, W-CDMA, etc. A WinIQSim-IQ data file can also be read so this means that a defined signal can be fed to the amplifier.

However, difficulties arise when generic modulated signals are used:

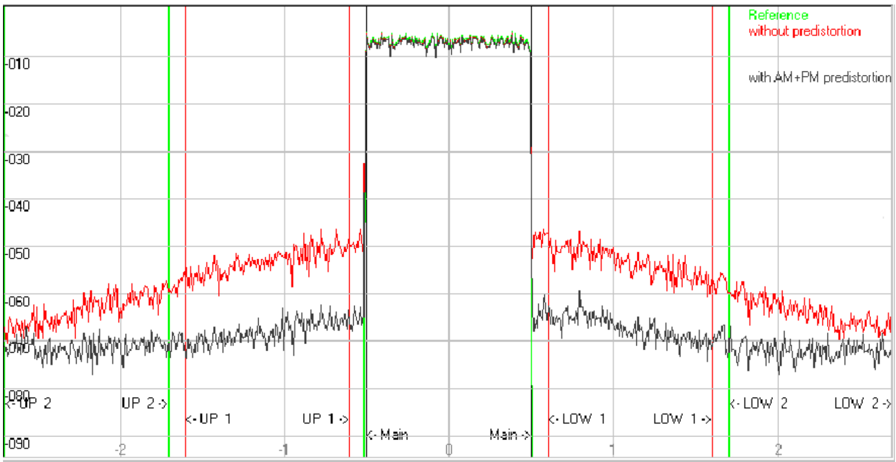
- The gain in the measurement path must be known so that the results can be scaled accordingly. To do this, the DUT gain is compensated for by means of attenuators and the remaining gain is compensated for by an automatic pre-measurement at a low level.
- The reference signal and the test signal must be exactly correlated in time. Approximate correlation can be obtained with an external trigger, but the remaining jitter is too great to allow the characteristic to be determined precisely. The figures below illustrate the problem:



Picture 1, 2

The left-hand Figure shows the results of an AM/PM distortion measurement (x axis = input level of the amplifier, y axis = phase difference between input and output of amplifier) without compensating for the time offset. The right-hand Figure shows the same measurement with time offset compensation.
However, by implementing various mathematical methods with the AMPTUNE software, these corrections can be made entirely automatically.

When the software is used, non-linearities can be significantly reduced and even completely eliminated as illustrated in the following diagram:



Picture 3

The Figure shows a 1 MHz noise signal The red curve shows the output spectrum of an amplifier with a non-linear characteristic. The increase in the adjacent-channel power can clearly be seen.
The black curve shows the same amplifier, but this time with a pre-distorted input signal. The adjacent-channel power is reduced to a level that is just measurable.

3 Software Features / Principle of Operation

AMPTUNE software has a facility for driving amplifiers with a suitably modulated signal and measuring the AM/AM and AM/PM compression characteristics. An SMIQ RF signal generator is modulated by an AMIQ IQ modulation source or the internal modulation generator of the SMIQ (SMIQ-B60). The signal is then amplified by the amplifier and measured with an FSIQ or FSP signal analyzer. The analyzer converts the signal to the baseband and stores the IQ data in its memory. The software determines the amplifier characteristic from the reference data and the measured values.

The software has the following features:

- Generates band-limited noise with settable bandwidth as a measurement signal. As an alternative, a WinIQSim signal can be used.
- Sets the frequency, level and bandwidth of the measurement signal.
- Sets the measurement bandwidth, the sampling depth and sampling rate of the signals to be tested.
- Sets parameters for automatic measurement sequence recording with sweeps versus frequency, level and/or signal bandwidth.
- Individual measurement with 1-stage (reference signal internally generated) or 2-stage (reference signal measured) measurement.
- Combined measurement with verification by measuring the improvement in adjacent-channel suppression with signal precorrection.
- Automatic measurement sequences.
- Combined of automatic measurement sequences and verification.
- Manual and/or automatic saving of results (characteristic data, IQ measured values, ACP improvement).

4 Hardware and Software Requirements

Hardware (Instruments)

The following equipment is required to perform the measurement:

- IQ signal source: AMIQ or Arbitrary Waveform Generator SMIQ-B60 as option for SMIQ
- Signal Generator SMIQ
- Signal Analyzer FSIQ with option FSIQB70 or Signal Analyzer FSP
- An attenuator to compensate for the DUT gain
- PC with Windows 95, Windows 98 or Windows NT
- If necessary, 1 or 2 precision attenuators RSG or RSP to improve the measurement range. These components are only required under critical VSWR conditions at the input and/or output of the amplifier and so are seldom needed

Software (Controller)

The controller does not need to meet any special requirements to run the software. Any PC with Windows 95, Windows 98, Windows Me, Windows 2000 or Windows NT can be used.

5 Installing the Software

Microsoft Installer is used to install AMPTUNE. The software must first be installed on the PC. To do this, run:

- InstMSIA.EXE under Windows 95
- InstMSIW.EXE under Windows 98 and Windows NT 4.0

Then start SETUP.MSI and install the program.

If you are using Windows 2000 or Windows Me or if you have already installed software with Microsoft Installer, Microsoft Installer is already installed on your PC. In this case, just start the SETUP.MSI file.

During installation, the program files are copied to the directory of your choice and an icon is created on the desktop of your PC to start AmpTune. Some demo IQ data files are stored in the IQFiles folder which is in the folder for the installed application.

The data are described in the README.TXT file in the same folder.

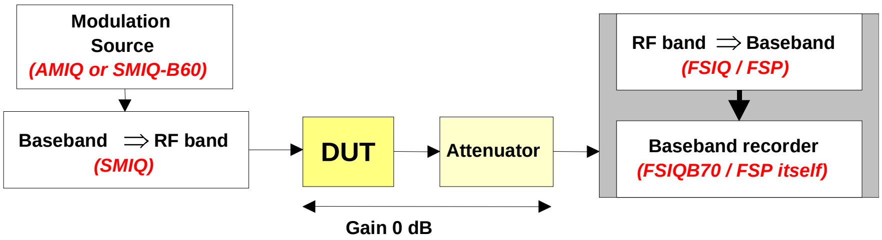
6 Connecting the Computer and the Instrument / Test Setup

Connecting up the instruments

Connect the IQ signal source, the signal generator and the signal analyzer to the PC via the IEC/IEEE bus. Each instrument must be assigned a unique IEC/IEEE-bus address.

Test setup

The software supports various measurement methods. The basic setup, however, is sufficient for almost all measurements and is shown below:



Picture 4

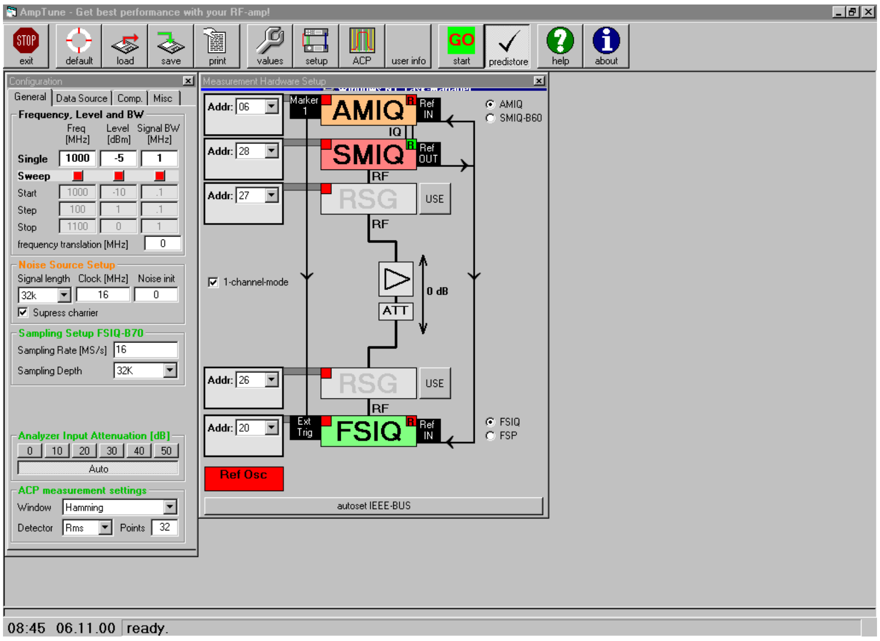
Install the software (see 5) and start the program. A window in which you can select the measurement method you want (1- or 2-stage method, external step attenuators) opens. The cabling for the selection that has been made is displayed.

Select "1-channel" with no external precision attenuators as the standard setting to perform a measurement.

If the DUT characteristics are to be determined optimally, the DUT gain must be compensated for so that the level at the signal analyzer input is the same as the level at amplifier input. It is not critical to have exactly the same level as software corrections are made. If the level is too low all that happens is a reduction in the measurement range. Furthermore, the instrument input must not be overdriven. Therefore, it is best to set a level between identical levels and output level 3 dB below the input level.

7 Starting the Software

Click on the icon on the desktop or select AMPTUNE in the start folder. The start screen is shown below:



Picture 5

The frequency, level, bandwidth, etc, can be set in the left-hand window. The right-hand window is used to set the test setup. The status bar at the bottom of the window gives the current program status.

8 On-line Help

To obtain detailed information about operating the software, start the software and call the on-line help by pressing [F1] or the button in the toolbar. The on-line help provides precise information on operating the software, the purpose of the various input fields, FAQs, etc.

To print the handbook, select the first item in the table of contents of the help function. All the sub-topics can be printed out with "Print". The whole handbook can be obtained as hard copy in this way.

9 References

- **F. Zavosh**, et all, “Digital Predistortion Techniques for RF Power Amplifiers with CDMA Applications”, *Microwave Journal,* Vol. 42, No. 10, October 1999, pp. 22-50
- **F. Zavosh**, et all, “Digital Predistortion Linearizes CDMA LDMOS Amps”, *Microwaves & RF,* March 2000, pp. 55-61+164
- **F. Bonn**, “Limitations in feed-forward-linearization”, *Microwave Journal,* August 2000, pp. 24-40 (Part I), September 2000, pp. 94-106 (Part II)
- **P. Kenington**, “Linearized RF Amplifier and Transmitter Techniques”, *Microwave Engineering Europe,* November 1998, pp. 35-50
- **P. Kenington**, “Methods Linearize RF Transmitter And Power Amps”, *Microwave & RF,* December 1998, pp. 102-116
- **P. Kenington**, “A Wideband Lineariser for Single and Multi-Carrier 3G CDMA, *IEEE Vehicular Technology Conference,* Fall ’99, Vol. 1, pp. 248-252

10 Ordering Information

Modulation generator		
AMIQ	Up to 16 Msamples I and Q	1110.2003.04
or		
SMIQ-B60	Up to 512 Ksamples I and Q	1136.4390.02
Vector signal generator		
SMIQ02B	0.3 to 2.2 GHz	1125.5555.02
SMIQ03B	0.3 to 3.3 GHz	1125.5555.03
SMIQ04B	0.3 to 4.4 GHz	1125.5555.04
SMIQ06B	0.3 to 6.4 GHz	1125.5555.06
Signal analyzer and options		
FSIQ3	20 Hz to 3.5 GHz	1119.5005.13
FSIQ7	20 Hz to 7 GHz	1119.5005.17
FSIQ26	20 Hz to 26.5 GHz	1119.6001.27
FSIQ40	20 Hz to 40 GHz	1119.6001.40
FSIQB70 (required)	25.6 MHz sampling rate	1119.6747.02
or		
FSP3	9 kHz to 3 GHz	1093.4495.03
FSP7	9 kHz to 7 GHz	1093.4495.07
FSP13	9 kHz to 13 GHz	1093.4495.13
FSP30	9 kHz to 30 GHz	1093.4495.30
RF precision attenuators		
RSG	0 to 5.2 GHz, 1 dB steps	1009.4505.02
RSP	0. 2.7 GHz, 0.1 dB steps	0831.3515.02

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