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MATRIX TECHNICAL NOTES
MTN-107

TEST SETUP FOR THE MEASUREMENT OF X-MOD, CTB, AND CSO USING A MEAN SQUARE CIRCUIT AS A DETECTOR AND A FAST FOURIER ANALYZER AS A READOUT

This note describes a greatly improved method for measuring cross modulation (X-MOD), composite triple beat (CTB), and composite second order (CSO) distortions. Besides providing greater accuracy this method is **insensitive to the phases of the components of composite distortions.** Linear detectors such as used in spectrum analyzers are phase sensitive and as a result their measurements may vary several dB over a period of several seconds. A more complete description along with a theoretical analysis of this method is covered in MATRIX TECHNICAL NOTE MTN-110.

The traditional method for making (CTB) and (CSO) measurements uses an RF spectrum analyzer for these measurements.

Because these signals have a bandwidth of approximately 20 KHz, there is a lower limit to the distortion that can be measured. This is determined by the weakest signal level and the system noise figure at the weakest signal point. For accurate measurements the measured distortion should be 5 to 10 dB above the noise floor. Corrections are sometimes possible for the case where the measurements are as little as 3 dB above the noise floor but at these levels other errors such as detector non-linearity and stability of the noise levels enter into the picture. Noise floors in the order of -90 dB are possible with some care. High gain devices present the more difficult problems because their input signals are necessarily small.

The MATRIX method of making these measurements overcomes some of these limitations by modulating the carriers with a low frequency and measuring the detected distortion in a narrow frequency band. The result is that noise floors of -110 dB are quite practical. The limitation of this measurement is no longer the RF bandwidth but rather the final bandwidth and of course the time the narrow bandwidth imposes on the measurement. Measurements of distortion in the order of -100 dB take about 10 seconds. Naturally, distortion levels further from the noise floor can be measured in much less time.

The MATRIX method of making these measurements measures the true carrier to distortion power ratio. Spectrum analyzers measure noise and noise-like signals with an error of 2.5 to 3 dB (with the true power being greater than the measured). This error is a result of the log display scale. This is the correction factor used when making carrier-to-noise ratio measurements. By convention, this correction is not used when making carrier to (CTB) or (CSO) measurements.

Since the MATRIX method measures true carrier-to-distortion power, +2.5 to +3 dB must be added to these measurements to provide agreement with traditional methods.

Instrument settings are described for each step in the tests. The setup block diagram is shown in figure 1.

The Multiple Frequency Signal Generator must provide a test signal containing distortion products much smaller than those to be measured. Each carrier must be individually controlled and must be adjusted as described below for the distortion tests.

The RF spectrum analyzer must have an IF output in the range of 3 to 30 MHz. This is then demodulated in the SQ1 Mean Square Module. Special Mean Square Modules are available for frequencies up to 400 MHz.

The FFT spectrum analyzer is used as a narrow band filter to reduce noise and allows for accurate amplitude measurements.

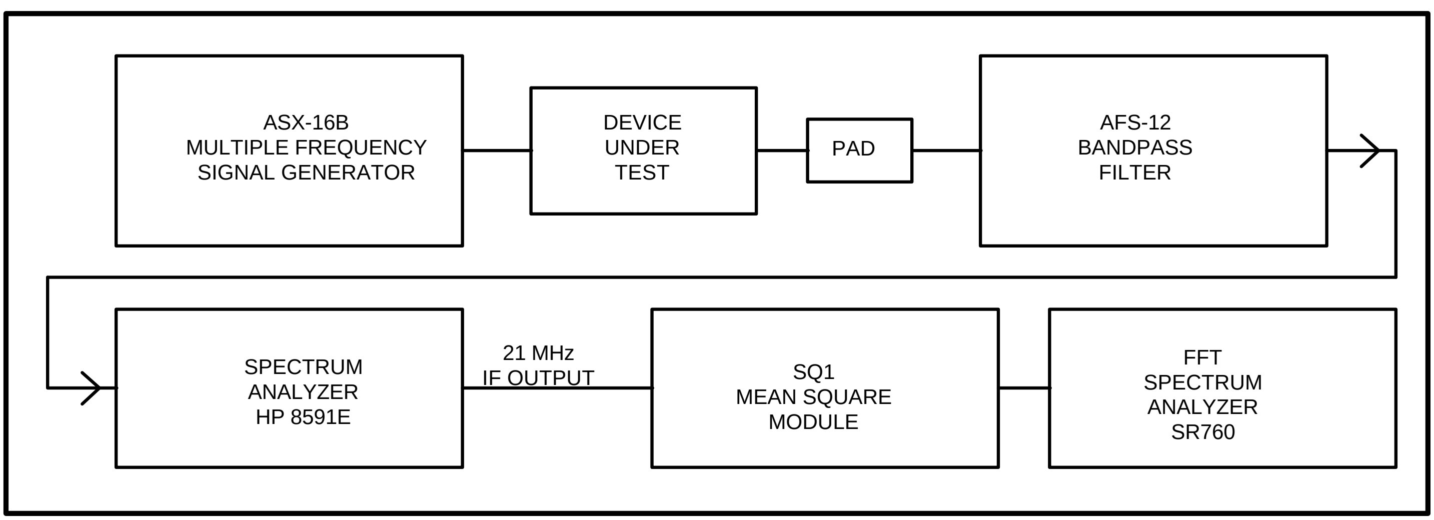

Fig 1, Block Diagram of Setup

Test Procedures:

Note: **BOLD LETTERING** indicates "hard keys" on the **RF** spectrum analyzer and **FFT** analyzer. Settings on these instruments not indicated do not affect measurements

1. Cross-Mod (X-MOD) Measurements

Generator Settings:	Required Carriers on 100% modulate all carriers at 15.75 KHz
Bandpass Filter Setting:	Set to frequency where measurement is to be made.

RF Spectrum Analyzer Settings:

FREQUENCY	
CENTER FREQUENCY	Set to frequency where measurement is to be made.
SPAN	0 HZ
BW	
RESOLUTION BW	1 MHz Preferred, 100KHz Minimum
AMPLITUDE	
REF LEVEL	0 dBm

FFT Analyzer settings:

MEAS
UNITS MENU
dBVrms
RETURN
WINDOW MENU
FLATTOP
RETURN

SCALE
Top Ref
(ENTER) **20**
dBVrms
Y/Div
(ENTER) **20**
dB

INPUT
INPUT RANGE
(ENTER) **10**
dBVrms

DISPLAY
MARKER WIDTH
(TOGGLE TO) NORM
MARKER SEEKS
(TOGGLE TO) MAX
GRID DIV/SCRN
(TOGGLE TO) 10

FREQ
SPAN
(ENTER) **1.56**
KHz
CENTER FREQ
(ENTER) **15.750**
KHz

(MARKER) MODE
Adjust manual control to bring marker rails to center screen.

NOTE: If desired the span may be reduced. The span setting determines the resolution bandwidth and so the noise floor. It also determines the time it takes to make the measurement. The measurement time is displayed as “Acq time” on the FFT screen. For 1.56 KHz span this is .25 sec. For a 48.75 Hz span this time is 8 sec.

You should have a signal in the middle of the screen with a marker at the peak. The magnitude of the marker should be about -10 dBVrms. The signal level output of the squaring circuit must be less than -5 dBVrms for linear operation. Adjustment of the RF spectrum analyzer may be required if the output of the squaring circuit exceeds -5 dBVrms.

(MARKER)>REF Y should = 0 dB   NOTE: Level must be less than -5 dBVrms

Generator setting: Measurement channel to CW

FFT Analyzer settings:

INPUT
INPUT RANGE
-30
dBVrms

Overload light should be off, if not adjust "input range" higher until overload indicator light is off.

READ Marker value “Y”, (Y is usually a negative number)

Cross Modulation = (Y - 6) dB

: Example

If Y = - 60 Then
X MOD = (- 60 - 6) = -66 dB

2. CTB Measurements

RF Spectrum analyzer settings:

FREQUENCY

CENTER FREQ	Set to frequency of measurement.
SPAN	0 Hz

BW

RES BW	30 KHz

AMPLITUDE

REF LEVEL	The Reference level should be adjusted so that the signal at the FFT analyzer is less that -5 dBVrms and greater than - 50 dBVrms. Lower levels will limit the dynamic range of the measurement.

Generator setting: 100% modulate all carriers with 1 KHz

FFT Analyzer settings:

MEAS
UNITS MENU
dBVrms
RETURN
WINDOW MENU
FLATTOP
RETURN

SCALE
Top Ref
(ENTER) **20**
dBVrms
Y/Div
(ENTER) **20**
dB

FREQ
SPAN
1.56
KHz
CENTER FREQ
1
KHz

(MARKER) MODE — If necessary, adjust marker rails to center screen. Marker level should be less than -5 dBVrms but greater than -50 dBVrms.

> REF — Y should read 0 dB.

Generator setting: Measurement carrier off (NOT LOW)

RF spectrum analyzer settings:

AMPLITUDE

REF LEVEL	Set reference to 50 dB below the level used for calibration.
ATTEN	Manual 0 dB. This should provide 50 dB gain increase when measured from the spectrum analyzer input to the auxiliary 21 MHz output. Not all analyzers operate this way so verification is required. The 50 dB number is used in calculating CTB as in the example below. If a particular analyzer provides some other gain change, use that value in the equation shown below when calculating CTB. For many applications a gain change of as little as 20 dB is sufficient to provide good results.

Read Y from the FFT analyzer (Y is usually a negative number)

CTB = (-50 + Y/2) dB

Example:

If Y = -60 dB then
CTB = (-50 -60/2) = -80 dB

3. CSO Measurements

RF spectrum analyzer settings:

FREQUENCY

CENTER FREQUENCY	Set to carrier frequency of the channel being measured.
SPAN	0 Hz

BW

RES BW	30 KHz

AMPLITUDE

REF LEVEL	The reference level should be adjusted so that the signal at the FFT analyzer is less than -5 dBVrms and greater than -50 dBVrms.
Generator setting:	100% modulate all carriers with 1 KHz.

FFT Analyzer settings:
MEAS
UNITS MENU
dBVrms
RETURN
WINDOW MENU
FLATTOP
RETURN

SCALE
Top Ref
(ENTER) **20**
dBVrms
Y/Div
(ENTER) **20**
dB

FREQ
SPAN
1.56
KHz
CENTER FREQUENCY
1
KHz

(MARKER) MODE	If necessary adjust marker rails to center screen. Marker level should be less than -5 dBVrms but greater than -50 dBVrms.

FFT Analyzer settings:

>REF	Y should read 0 dB.
Generator Setting:	Measurement carrier off (NOT LOW).

RF Spectrum analyzer settings:

FREQUENCY	
CENTER FREQUENCY	Set to channel frequency +/- 1.25 MHz for a NTSC system, or to the frequency where the CSO is expected.
SPAN	0 Hz
BW	
RES BW	30 KHz
AMPLITUDE	
REF LEVEL	Set reference level 50 dB below the level used for calibration.
ATTEN	Manual 0 dB.
	This should provide 50 dB gain increase when measured from the spectrum analyzer input to the auxiliary 21 MHz output. Not all analyzers operate this way so verification is required. The 50 dB number is used in calculating CSO as in the example below. If a particular analyzer provides some other gain change, use that value in the equation shown below when calculating CSO. For many applications a gain change of as little as 20 dB is sufficient to provide good results.

Read Y from the FFT analyzer (Y is usually a negative number).

CSO = (-50 + Y/2) dB (as in CTB measurements)

Equipment List:

For these tests the following equipment was used:

Multiple Frequency Signal Source	Matrix Test Equipment Inc. MODEL ASX-16C
Band Pass Filter	Matrix Test Equipment Inc. MODEL AFS - 12
Mean Square Module	Matrix Test Equipment Inc. MODEL SQ1
RF Spectrum Analyzer	Hewlett Packard MODEL 8591E
FFT Spectrum Analyzer	Stanford Research Systems MODEL SR760

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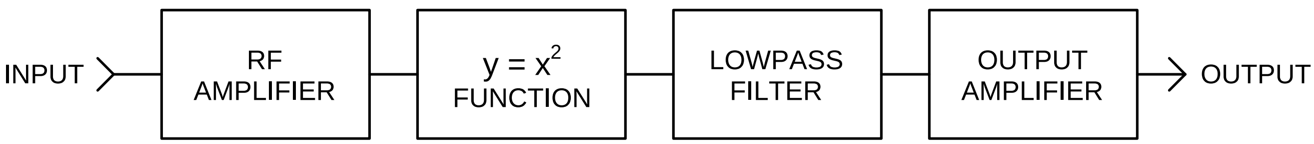
MODEL SQ1

MEAN SQUARE MODULE

THIS UNIT GENERATES THE MEAN OF THE SQUARE OF AN INPUT SIGNAL

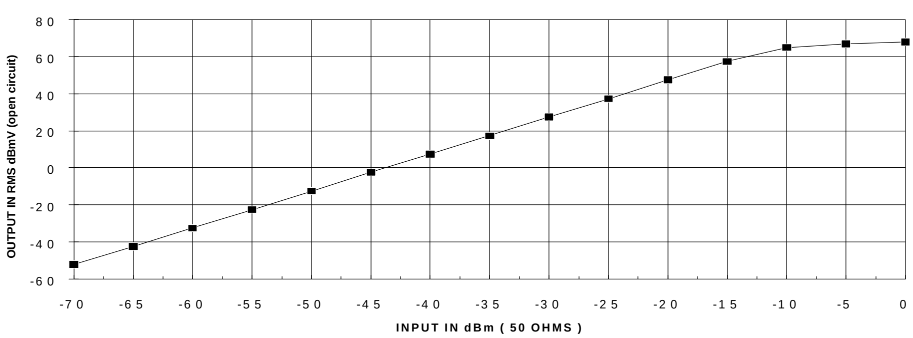


BLOCK DIAGRAM

GENERAL SPECIFICATIONS

INPUT FREQUENCY	10 to 30 MHz
OUTPUT FREQUENCY	DC to 30 KHz
MAXIMUM USEABLE INPUT	- 15 dBm (50 OHMS)
OUTPUT	NOMINAL 2 VOLTS DC FOR -15 dBm INPUT
OFFSET VOLTAGE	< 0.005 VOLTS
INPUT LEVEL FOR 3 dB S/N RATIO WITH OUTPUT BANDWIDTH OF 1 Hz	- 75 dBm
POWER REQUIRED	± 15 VOLTS DC, 30 mA

MODEL SQ1 RF INPUT Vs DEMODULATED OUTPUT



INPUT:
21 MHz. CARRIER
100% DOWNWARD MODULATED
BY A 1 KHz SQUARE WAVE

OUTPUT:
MAGNITUDE OF THE 1 KHz
COMPONENT OF THE
DEMODULATED OUTPUT