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HP References in this Application Note

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SPECTRUM ANALYSIS . . .

Using the HP 11517A External Mixer to 40 GHz

INTRODUCTION

Spectrum analyzers, such as the HP 8555A and 8565A, are able to directly measure signals up to 18 and 22 GHz, respectively. In order to measure signals above this frequency, an HP 11517A external mixer must be used in place of the analyzer's first mixer to convert an input frequency down to the analyzer's first intermediate frequency (IF).

There are two techniques used to produce this IF, harmonic mixing and fundamental mixing. Harmonic mixing uses the harmonics of the analyzer's internal local oscillator (LO) for mixing, while fundamental mixing uses the fundamental frequency from an external sweep oscillator to provide the LO for mixing. This application note will emphasize measurement techniques using harmonic and fundamental mixing with the spectrum analyzer and external mixer up to 40 GHz.

MIXER POWER LIMITATIONS

The mixer's power limitations are of primary importance. Table 1 summarizes the input signal power limitations of the HP 11517A external mixer for both harmonic and fundamental mixing.

	Harmonic Mixing	Fundamental Mixing
Maximum RF Signal Input Level (Mixer Damage Level)	> 0 dBm	> 0 dBm
Saturation Input Level (<1 dB Gain Compression)	> -15 dBm	> -15 dBm
Optimum Input Level (Spurious Products < Noise)	-20 dBm	-35 dBm
Typical Average Noise Level (10 kHz Resolution Bandwidth)	< -60 dBm	< -85 dBm

Table 1. Signal power limitations of the HP 11517A external mixer measured at the mixer's waveguide input port. The fundamental mixing limitations assume an LO power of 0 dBm (1 mW) applied to the mixer's waveguide input port.

THEORY OF OPERATION

Harmonic Mixing

Using the set-up shown in Figure 1, with the spectrum analyzer switched into one of its external mixer bands and an input signal (RF) applied to the mixer, three signals are present at the analyzer's external mixer BNC port: the analyzer's local oscillator (LO), the intermediate frequency (IF), and the external mixer bias (I_{BIAS}).

The LO is the spectrum analyzer's first local oscillator which sweeps from approximately 2 to 4 GHz and generates harmonics in the mixer. These harmonics mix with the RF input signal to generate a 2.05 GHz intermediate frequency (IF).

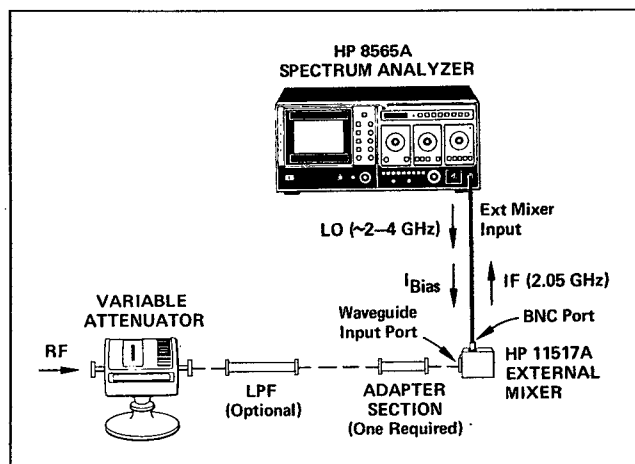


Figure 1. Harmonic mixing set-up.

The IF travels back to the analyzer, is passed through a 2.05 GHz bandpass filter network in the analyzer, is processed by further filtering and amplification, is detected, and finally displayed on the CRT. Since the 2.05 GHz IF is generated for more than one unique LO frequency, the signal identifier switch must be used to determine the correct response. Use of the external mixer does not affect the signal identifier process.

The optional LPF may be used to simplify signal identification by limiting higher frequency signals from the mixer. The filter's cutoff frequency should be just above the frequency band under measurement.

Because the BNC coaxial cable is moderately lossy in the frequency range of the LO and IF, the cable cannot become excessively long. Therefore, it is best to use the HP 10503A cable supplied with the mixer or up to 1.2 meters (4 feet) of RG-58 (50 Ω) coaxial cable.

The I_{BIAS} signal is a dc current controlled by the external mixer BIAS adjustment on the spectrum analyzer. This current will bias the mixer diode for minimum conversion loss by changing the diode conduction angle. In harmonic mixing, the optimum conduction angle varies with the LO frequency and harmonic number. To optimize the mixer, adjust the BIAS to peak the signal. Since more than one peak normally occurs, it is important to adjust the BIAS to the maximum peak. The best frequency response (flatness) is achieved by optimizing the mixer for every 500 MHz change in RF input signal frequency or whenever frequency bands are changed.

The EXT MIXER INPUT port bypasses the input attenuator and the first mixer of the analyzer. Although the attenuator will not affect the CRT display, it is coupled to the reference level control and will affect the reference level reading. Therefore, the attenuator must not be changed after an amplitude reference has been chosen. On analyzers with internal preselection, such as the HP 8565A, the preselector is also bypassed. Hence, the PRESELECTOR PEAK control will not affect the display. All other controls on the analyzer function as usual.

Fundamental Mixing

Fundamental mixing, although it requires a high frequency sweep oscillator, has several advantages over harmonic mixing. Because mixing is performed with the fundamental frequency of the LO, only two responses, separated by twice the IF frequency (4.1 GHz), are produced by the mixer and displayed on the spectrum analyzer for each RF signal present at the input. This greatly reduces the effort involved in signal identification. Fundamental mixing also enhances sensitivity by as much as 20 dB and reduces the frequency response (flatness) to as little as ± 1 dB.

In the fundamental mixing mode, the external mixer is connected to the spectrum analyzer as shown in Figure 2.

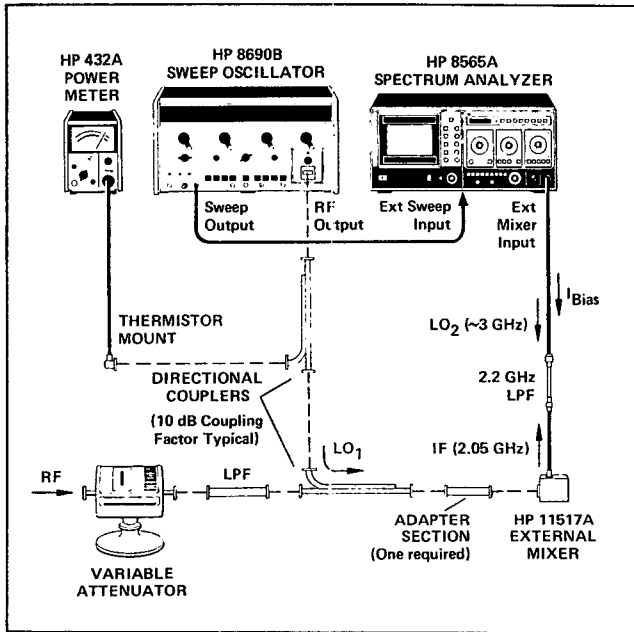


Figure 2. Fundamental mixing set-up.

The sweep oscillator is the heart of the system providing the local oscillator (LO_1) for mixing and the horizontal sweep for the analyzer. The sweeper controls the center frequency, frequency span, and sweep time. With sweepers such as the HP 8690 Series, the START/STOP mode is used for wide frequency spans and the Δf mode is used for narrow frequency spans.

Amplitude calibration is dependent on the frequency span, resolution bandwidth, video filter bandwidth, and sweep time. To check for a calibrated display, increase the sweep time by at least a factor of three. If the amplitude does not change, the display was calibrated. If the amplitude increases, continue increasing the sweep time until the amplitude reaches a maximum.

For best frequency response (flatness), the sweeper's LO power is held to a constant value and monitored with a power meter or an automatic leveling control (ALC) circuit. This LO power is typically adjusted to 0 dBm (1 mW) at the mixer for best sensitivity. Lower power values may be used, but sensitivity is reduced and flatness is worse.

Depending upon the sweep oscillator's sweep output voltage and the spectrum analyzer's sweep input voltage, readjustment of the horizontal CRT trace may be necessary. For instance, when using the HP 8565A analyzer with the HP 8690 Series sweeper, a 100 k Ω potentiometer is used in series between the analyzer and the sweeper to reduce the horizontal sweep voltage. The HP 8555A

(8552A/B) analyzer's horizontal gain and position controls will usually eliminate the need for such an interface. See Appendix B for more information on input and output sweep characteristics.

With the spectrum analyzer switched into one of its external mixer bands and an input signal (RF) applied to the mixer, three signals are present at the analyzer's external mixer BNC port: the analyzer's local oscillator (LO_2), the immediate frequency (IF), and the external mixer bias (I_{BIAS}).

Since the sweep oscillator will be providing the local oscillator (LO_1) for the mixer, the spectrum analyzer's local oscillator (LO_2) must be filtered out. This is accomplished by first tuning the analyzer to the middle of the frequency band (setting $LO_2 \approx 3$ GHz) and then inserting a 2.2 GHz low-pass filter between the analyzer and the mixer.

The RF and LO_1 signals generate two mixing products, equal in amplitude and separated by twice the IF frequency (4.1 GHz), for each RF signal present at the input (neglecting intermodulation and harmonic distortion products). The IF travels to the analyzer, into a 2.05 GHz band-pass filter network in the analyzer, is processed by further filtering and amplification, is detected, and is finally displayed on the CRT. With the analyzer's frequency span control adjusted to 1 MHz/DIV, the signal identifier switch must be used to determine if the RF input signal is 2.05 GHz higher or lower than LO_1 . With the analyzer set to a positive (+) IF mixing mode (i.e., 6^+ or 10^+) and a narrow frequency span (use the sweeper's Δf mode), signals which identify with the smaller image to the left are 2.05 GHz lower than LO_1 . Signals which identify with the smaller image to the right are 2.05 GHz higher than LO_1 . Figure 3 demonstrates this effect.

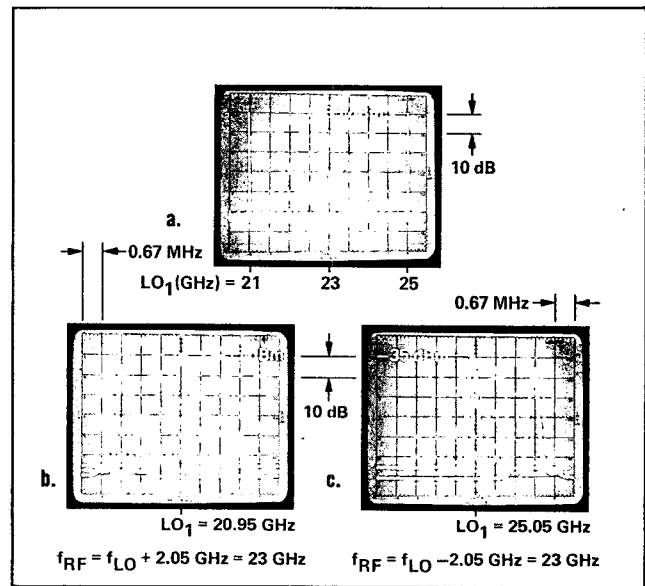


Figure 3. Signal identification using fundamental mixing. (a) shows two signal responses of equal amplitude and separated by 4.1 GHz for a 23 GHz RF input signal. (b) and (c) show how the lower and upper signal responses were identified using the signal identifier switch. This example used a positive (+) analyzer IF mixing mode (i.e., 6^+ or 10^+).

Generally, the signal identifier switch will not give a two-division response. The distance between responses depends on the frequency span selected by the sweep oscillator. The smaller this is, the further apart the two responses will be. All that is important is the direction the smaller response is from the larger one.

Use of the analyzer's negative (-) IF mixing mode (i.e., 6- or 10-), available on some analyzers, will cause the smaller image to identify in the opposite direction from the example in Figure 3. Thus, if the above rule were applied when using the analyzer's negative (-) IF mixing mode, an error of 4.1 GHz would result.

Harmonic mixing distortion may occur if higher frequency signals present at the RF input port mix with the harmonics of the LO₁. To eliminate these errors, a waveguide low-pass filter is inserted in front of the mixer's waveguide input port. The filter's cutoff frequency should be just above the frequency band under measurement.

Occasionally some spurious signals caused by the analyzer's local oscillator (LO₂) may appear. These spurious signals may be eliminated from the display by adjusting the analyzer's frequency tune control.

CALIBRATION PROCEDURE

The spectrum analyzer may be calibrated to read absolute power using an external RF calibration signal in the frequency range of interest. This is done by using both the INPUT ATTEN control and the REF LEVEL CAL (HP 8555A = AMPL CAL) adjustments on the analyzer. Since the input attenuator is bypassed, it has no effect on the signal but will change the reference level readout. Thus, the INPUT ATTEN control provides a method of calibrating the analyzer to within ±5 dB (attenuator has 10 dB steps) of the calibration signal amplitude. To adjust within the ±5 dB limit, use the REF LEVEL CAL adjustment to bring the display into an absolute power calibration.

The following procedure may be used to calibrate the analyzer in either the harmonic mixing or fundamental mixing modes.

1. INITIALIZE CONTROLS: Calibrate the analyzer as usual using the internal calibration signal. Then, use the control settings given in either the harmonic or fundamental mixing measurement procedure.
2. INPUT SIGNAL: Input an RF calibration signal of known frequency and amplitude. For greatest accuracy, the frequency should be as close to anticipated signals to be measured as possible. If signals are to be measured across the entire frequency band, the calibration frequency should be near the middle of that band. The approximate calibration signal amplitude should be -20 dBm for harmonic mixing or -35 dBm for fundamental mixing.
3. TUNE AND IDENTIFY SIGNAL: See the appropriate measurement procedure sections.
4. ADJUST MIXER BIAS: Adjust the mixer BIAS until the signal reaches its maximum peak. Check the sweep time to insure a calibrated display.
5. BRING SIGNAL NEAR TOP OF CRT: Position the displayed signal as close as possible to the reference level graticule line using only the coarse (10 dB steps) reference level control.
6. COARSE ADJUST: Starting with the analyzer's INPUT ATTEN and reference level fine (vernier) controls set to 0 dB, adjust these controls to make the analyzer's reference level equal to the calibration signal amplitude. In fundamental mixing the reference level and calibration signal amplitude cannot be made equal. In this case it is necessary to note an offset (i.e., 10 dB, 20 dB) to apply to future amplitude measurements.
7. FINE ADJUST: Position the displayed signal on the reference level graticule line using the REF LEVEL CAL adjustment.

8. CALIBRATION COMPLETE: The analyzer is now amplitude calibrated for the frequency band chosen above.

MEASUREMENT PROCEDURE

Harmonic Mixing

Measurements may be made using harmonic mixing with the following procedure.

1. INITIALIZE ANALYZER CONTROLS: Use the set-up in Figure 1, the desired external mixer frequency band, a wide resolution bandwidth (≥ 300 kHz), and a wide frequency span (≥ 200 MHz/DIV).
2. CONNECT SIGNAL: The variable attenuator insures that the mixer's power limitations are not exceeded.
3. TUNE ANALYZER TO SIGNAL: Tune the analyzer to the desired frequency. If a signal response cannot be found, slowly adjust the BIAS until a response appears or decrease the resolution bandwidth for better sensitivity. Reduce the frequency span to 1 MHz/DIV while keeping the signal to be measured centered with the tuning control.
4. IDENTIFY SIGNAL: Identify the signal using the signal identifier switch.
5. ADJUST MIXER BIAS: Adjust the mixer BIAS until the signal reaches its maximum peak. The BIAS should be adjusted for every 500 MHz change of RF input signal frequency or whenever the frequency band is changed.
6. MEASURE SIGNAL: Use the reference level controls to position the signal on the reference level (top CRT graticule line). Record the frequency and amplitude of the signal.

Fundamental Mixing

Measurements may be made using fundamental mixing with the following procedure. If the calibration procedure was not followed, adjust the mixer BIAS on the first measurement. The mixer BIAS only needs to be adjusted once.

1. INITIALIZE CONTROLS: Use the set-up in Figure 2 and set the controls as follows:
Spectrum Analyzer,
frequency band = any positive (+) external mixer band (i.e., 6⁺ or 10⁺)
frequency tune = to middle of above band (setting LO₂ \approx 3 GHz)
frequency span = 1 MHz/DIV
resolution bandwidth ≥ 300 kHz
Sweep Oscillator,
frequency span = widest possible span
sweep time = 5 seconds per sweep
power output = 0 dBm (1 mW) at mixer
2. CONNECT SIGNAL: The variable attenuator insures that the mixer's power limitations are not exceeded.
3. TUNE SWEEPER TO SIGNAL: Input signals near the middle of the swept band produce two responses while those near the edge of the band produce only one. Reduce the frequency span using the sweeper's Δf control while keeping the signal to be measured centered with the CW control.
4. IDENTIFY SIGNAL: With the frequency span sufficiently narrow, use the signal identifier switch to determine if the RF input signal is 2.05 GHz higher or lower than the sweep oscillator frequency (LO₁).
5. MEASURE SIGNAL: Check the sweep time to insure a calibrated display. Use the reference level controls to position the signal on the reference level (top CRT graticule line). Record the frequency and amplitude of the signal.

ACCURACY CONSIDERATIONS

Measurement accuracy is dependent upon the spectrum analyzer, the external RF calibration signal, and, in the case of fundamental mixing, the sweep oscillator. The tuning accuracy using harmonic mixing is dependent upon the accuracy of the spectrum analyzer, while in fundamental mixing it is dependent upon the accuracy of the sweep oscillator. The tuning accuracy is typically within 1% of the center frequency for narrow frequency spans. The amplitude accuracy depends upon the analyzer, calibration signal, and the system's frequency response (flatness). The system's frequency response may be eliminated by using RF substitution techniques to achieve amplitude accuracies typically within ± 2 dB.

Examples of combined sensitivity and frequency response with the HP 11517A external mixer are given in Figures 4 and 5.

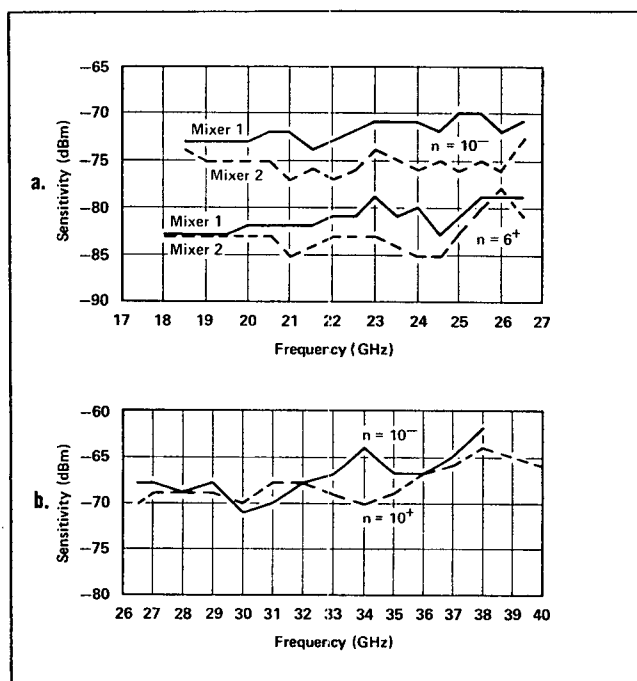


Figure 4. Examples of combined sensitivity and frequency response in a 10 kHz resolution bandwidth using harmonic mixing with an HP 8555A Spectrum Analyzer. (a) compares the sixth and tenth harmonic mixing bands each using two different HP 11517A mixers. The HP 8565 produces similar results. (b) compares the similarity of the analyzer's tenth harmonic mixing bands using the mixer 1. Measurements were made adjusting the mixer BIAS every 500 MHz.

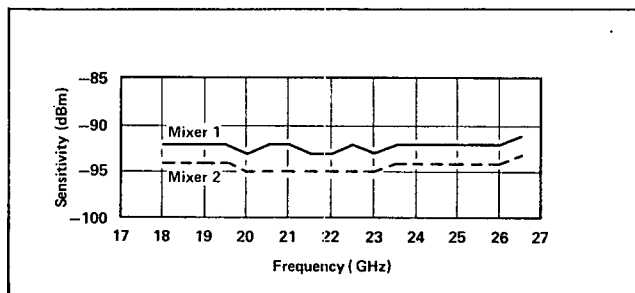


Figure 5. Example of combined sensitivity and frequency response in a 10 kHz resolution bandwidth using fundamental mixing and an HP 8555A Spectrum Analyzer with two different HP 11517A mixers. Other frequency bands yield similar improvements over harmonic mixing.

APPENDIX

A. Recommended Equipment

Following is a brief list of the equipment used in this application note.

Mixer Components

HP Model	Frequency (GHz)	HP Band Designation	Description
11517A	12.4 - 40.0	—	Mixer (adapter required)
11518A	12.4 - 18.0	P	Adapter section
11519A	18.0 - 26.5	K	Adapter section
11520A	26.5 - 40.0	R	Adapter section

Sweep Oscillator

HP Model	Frequency (GHz)	Description
8690A/B	—	Mainframe
8695A ¹	12.4 - 18.0	BWO plug-in
8696A ¹	18.0 - 26.5	BWO plug-in
8697A ¹	26.5 - 40.0	BWO plug-in

Low Pass Filters

HP Model	Passband (GHz)	Stopband (GHz)	Description
360C	≤ 2.2	≥ 2.7	Coaxial LPF
P362A	12.4 - 18.0	23 - 54	Waveguide LPF
K362A	18.0 - 26.5	31 - 80	Waveguide LPF
R362A	26.5 - 40.0	47 - 120	Waveguide LPF

B. Sweep Input/Output Characteristics

Sweep Oscillator

Sweep Output Characteristics

HP Model	Approximate Output Voltage	Nominal Output Impedance
8620	0 to +10 V	10 k Ω
8690	0 to +15 V	10 k Ω

Spectrum Analyzer

Sweep Input Characteristics

HP Model	Approximate Input Voltage	Nominal Input Impedance
8551B/851B	0 to +15 V	100 k Ω
8552A (pre-1970)	0 to +8 V	1 M Ω
8552A/B (mod TG-1) ²	0 to +8 V	48 k Ω
8565A	0 to +10 V	100 k Ω

¹ To simplify measurements, BWO plug-ins are available as a special option with a 2 GHz frequency offset.

² The designation "mod TG-1" will appear on all HP 8552A/B IF sections made subsequent to 1969.