Application Note 286-2

Accurate Mixer/Amplifier Compression Measurement Using the 8901A Modulation Analyzer

HEWLETT PACKARD

The steady increase in performance requirements of modern RF and microwave systems complicates the process of specifying and selecting the components needed to build these systems. Care in selecting the component best suited to a given application not only saves time and money but also minimizes problems in system integration. In microwave systems, mixers and amplifiers are key components. The following discussion is dedicated to these components; however, reference is made only to mixers, unless a distinction is required.

This application note focuses on measuring compression and describes a novel measurement technique using Hewlett-Packard's 8901A Modulation Analyzer. Other presently available techniques for measuring compression have been cumbersome at best, mainly because of inaccuracies in determining the compression point in a mixer or an amplifier. Hewlett-Packard's 8901A Modulation Analyzer allows measurement of the compression point conveniently and with great precision, thereby virtually eliminating guess work and making it possible to use the linear dynamic range to its maximum.

In mixers, performance parameters such as dynamic range, compression and distortion are closely related and they interact. Since they have a direct impact on system performance, a brief review of their relationship is useful.

Compression and Dynamic Range

Compression occurs when the intermediate frequency (IF) output level in a mixer no longer tracks linearily as the input power is increased (Figure 1). This is an important consideration in selecting mixers for certain applications. Simply defined, *Compression Level, or Compression Point, is the maximum RF input level for which the mixer will provide acceptably linear performance.*

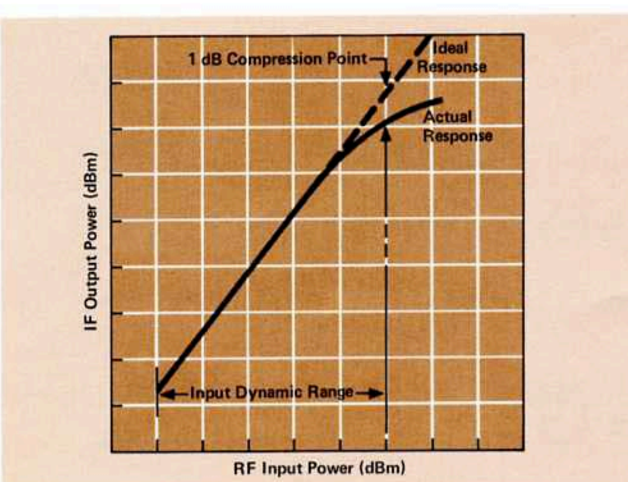

Figure 1. Mixer Transfer Characteristics.

Mixers can be operated anywhere in their useable range of operation which extends from the minimum detectable signal level to saturation level. Where in this useable range the mixer is operated depends upon the application. For example, in electronic communications, mixers are normally operated in the linear dynamic range. There are other applications where mixers are operated closer to saturation. The focus of this note is on applications where mixers are operated in the linear dynamic range. By definition, *the linear dynamic range of a mixer extends from the minimum detectable signal level on the lower end to the compression level on the upper end.* Within this range, the output level tracks the RF input level linearly. At compression, however, the output level does not exactly track the input level. As a result, the conversion loss in mixers increases and the gain in amplifiers decreases, or compresses.

Compression in mixers occurs in different amounts at different levels of the input signal and needs a defined reference point. For example, the 1-dB compression point appears frequently on mixer and amplifier data sheets and is becoming an industry standard. Typically, acceptable compression points can vary from 0.1 dB up to 1 dB, depending on system requirements. It should be noted that the compression point in mixers is specified at a given local oscillator (LO) level. Usually, the higher the LO level, the higher the compression point.

Why Compression is Important

Compression provides important information about the behavior of mixers. Basically, compression is a measure of non-linearity. It determines where a given mixer should be operated to achieve maximum linear dynamic range with minimum distortion. As soon as the mixer begins to compress, it introduces amplitude distortion to the system. Furthermore, the extent of this distortion is directly related to the amount of compression. This is one reason why system designers, especially in communications, are often anxious to operate mixers well below their specified compression levels.

Intermodulation and Distortion Measurement

One valid way of measuring amplitude distortion in a system is to measure the intermodulation performance. This usually involves measuring the level of two-tone, third-order intermodulation products. *The higher the third-order level, the higher the distortion.*

Two-tone intermodulation distortion is the result of two signals equal in amplitude being applied to the mixer's RF input at the same time. These signals may generate harmonics, mix with each other, then beat with the mixer local oscillator frequency according to the following expressions:

$$(2F_1 \pm F_2) \pm F_{LO}$$
$$(F_1 \pm 2F_2) \pm F_{LO}$$

where F_1 & F_2 are the two RF input frequencies, and F_{LO} is the local oscillator frequency.

These expressions describe the third-order, two-tone intermodulation products. The third-order products are usually of primary interest because of their relatively large magnitude and because they are difficult to filter from the desired output.

A convenient method of determining the third-order two-tone intermodulation response of a mixer is to find the *third-order intercept point. This is a theoretical point on the RF Input/Output curve where the desired output signal and the third-order product become equal in amplitude as the RF input level is increased.* The third-order intercept point is obtained graphically by extending the measured third-order and fundamental responses until they intercept as shown in Figure 2. Once the intercept point is established for a given mixer, the intermodulation product level at the output can be calculated from the following expression:

$$P(n) = I(n) - n \cdot [I(n) - M]$$

where $I(n)$ = nth order intercept at the output (dBm)
M = level of fundamental tone at the output (dBm).

The intermodulation performance can also be determined graphically, at a given RF input level, from the information given in Figure 2. As the graph shows, the fundamental response varies on a 1:1 slope, whereas the third-order response varies on a 3:1 slope. This means that reducing the RF input level to the mixer produces a 2:1 improvement (in dB) in the third-order response. However, this technique of reducing intermodulation results in poor efficiency, especially when applied to linear power amplifiers.

The difference between the compression point and the third-order intercept point is subtle but significant. The compression point measures the acceptable deviation of the mixer response from the ideal linear response. It is also the upper limit of the linear dynamic range. It is a measurable quantity, whereas the third-order intercept point is a theoretical point that determines the distortion suppression capability of a mixer. In other words, distortion is a consequence of compression and the intercept point approach is used to determine how well the mixer minimizes this distortion.

Although these two points represent two distinct performance factors, an empirical, though not exact, relationship does exist between them. As a rule-of-thumb, the third-order intercept point in mixers is typically 15 dB above the 1-dB compression point. This rule-of-thumb provides a quick and approximate method of predicting the intermodulation distortion of a mixer when either of these points is known.

Methods of Measuring Compression

Until the advent of the 8901A Modulation Analyzer the usual method of measuring compression in mixers and amplifiers was to vary the level of the input signal while monitoring the level of the output signal with a power meter or spectrum analyzer. Compression occurs when the IF level begins to deviate from linearity as the input level is increased. This technique was adequate but not accurate enough to resolve small compression ratios. Inherent uncertainties make compression measurements of 1 dB or less either difficult or impractical.

Power meters measure total power, including harmonics, images, and local oscillator feed-through. Filters could be used to suppress these unwanted signals but they tend to degrade output match. Consequently, care has to be taken to ensure low-reflection connections and

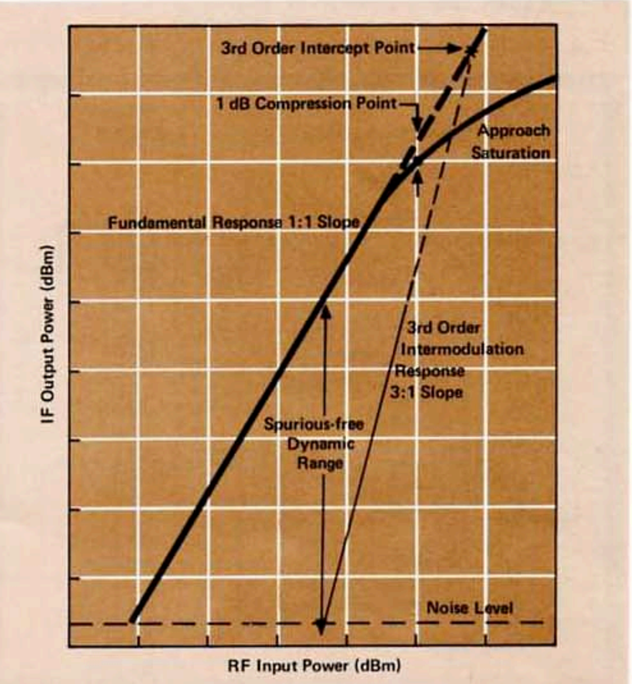

Figure 2. Mixer Transfer Characteristics with Third-Order Intercept Point.

enough isolation to make the effects of mismatch insignificant. Nevertheless, the combination of output mismatch and unwanted responses usually introduce uncertainties that are difficult or impractical to analyze and correct. Although spectrum analyzers filter out unwanted responses, their typical accuracies over the entire dynamic range are about ±1.5 dB with some improvement when measurements are made over a narrower range.

The 8901A Modulation Analyzer Method

The technique described in this application note uses the 8901A Modulation Analyzer and yields better accuracy, sensitivity, and repeatability than obtainable with power meters or spectrum analyzers. The method is based in principle on amplitude-modulating the mixer input signal with a square-wave to a depth of approximately 33%. As shown in Figure 3, modulation causes the input test signal to oscillate between a reference level, B, and a level approximately twice that, A, thereby dynamically switching the mixer between two operating levels. This modulated signal is applied to the mixer under test through a step attenuator (Figure 4), that allows calibrated control of the test signal's level. The modulating signal is then recovered at the IF output by the 8901A Analyzer and displayed on an oscilloscope.

At some level of the input signal, the IF output of the mixer begins to compress and the peak level of the demodulated IF signal decreases, as indicated by A'. This change in peak level, which is caused by compression, is measured as a change in the AM depth, and it can be shown that compression is directly related to AM depth (see appendix). Since the 8901A Modulation Analyzer measures AM depth with 0.01% resolution and 1% of reading accuracy, it measures compression with the same resolution and accuracy. Furthermore, this technique is insensitive to system mismatches because modulation is a relative quantity, and the variations in SWR that affect the mixer output do not affect the modulation on it.

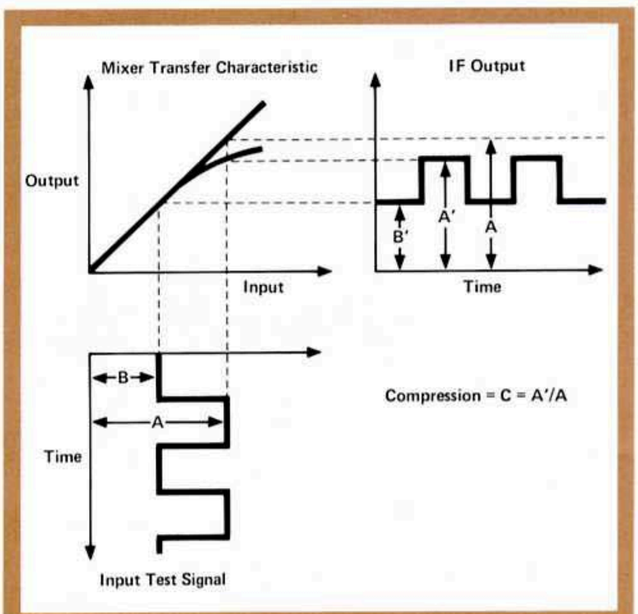

Figure 3. How Compression Changes AM Depth of Square-Wave Modulated RF Signal.

Measurement Procedure

Figure 4 illustrates the set-up for measuring compression manually with the 8901A Analyzer. The signal generator is adjusted initially to a reference level and is not varied during the rest of the measurement because changing the generator level changes the reference AM depth and introduces errors. The level of the modulated test signal into the mixer is controlled by two step attenuators (1 dB/step and 10 dB/step). The oscilloscope is used to view the demodulated signal and is highly recommended as it provides important information about the demodulated signal (ringing, over-shoot, amplitude distortion). To measure mixer compression with the Modulation Analyzer, the following procedure is recommended:

1. Construct the test set-up shown in Figure 4.
2. Adjust the signal generator to the desired RF test frequency. Amplitude-modulate this test signal with a 10 kHz squarewave from the function generator. Set the amplitude of the modulating signal (square-wave) to produce 33% AM on the RF test signal.
3. Select the desired LO frequency; one that produces an IF within the range of 150 kHz to 1300 MHz (the 8901A Analyzer measuring range). Care must be taken to prevent extraneous signals out of the mixer from coming so close to the desired output signal that they might pass through the IF filter in the 8901A Analyzer. IF filter bandwidth considerations are described in detail in Application Note 286-1.
4. Adjust LO power to the desired operating level. Double-balanced mixers typically require +10 dBm of LO power.
5. Manually tune the 8901A Analyzer to the resulting IF, and select the following functions on the analyzer:
   AM Mode
   Average Detector
   20 kHz Low-pass Filter
   40% AM Range (2.1 SPCL)
   Fast AM ALC (6.1 SPCL)
6. Adjust the signal generator level and the step attenuators to produce an RF signal level into the mixer approximately 20 dB below the LO level. This assures that the mixer is not already in compression.

7. Take a reference AM reading (M) on the 8901A Analyzer.
8. Increase the RF level to the mixer by reducing attenuation until the amplitude of the square-wave displayed by the oscilloscope compresses by a noticeable amount (% AM decreases). Take another AM reading (M′). Calculate the compression ratio (A′/A) using the following expression:

$$C_{db} = 20 \log \left(\frac{G-M}{G+M}\right) \cdot \left(\frac{G+M'}{G-M'}\right)$$

where C = compression ratio in dB
M = AM depth reading (uncompressed)
M′ = AM depth reading (compressed)
G = 1.11 (hardware detector gain in the 8901A — see appendix for explanation).

This expression is valid only when B = B′ (Figure 3), indicating that level B is uncompressed. Thus, it applies only to small compression ratios, less than about 0.7 dB. For higher compression ratios (level B is compressed and B ≠ B′), the following expression is more accurate:

$$C_{cor(dB)} = 20 \left[\log C' + \log C\right] \text{ (see appendix)}$$

where C_{cor} = corrected compression
C = C(L) which is the compression due to the higher modulating level (A).
C′ = C(L-6) which is the compression due to the lower modulating level (B). This level, in square-wave with 33% AM, is 6 dB lower than the higher level (A).

With square-wave modulation at 33% AM depth, the two modulating levels differ by 6 dB. Therefore, correction is recommended for inputs 6 dB higher than the level that first produces perceptible compression (0.1 dB). This can be best understood from a specific example. Figure 6 shows a sample compression curve where compression is plotted against the peak input level for a typical mixer. Suppose that the compression at +6 dBm input level is to be determined. From this plot, assuming it is not corrected, the compression at +6 dBm input level is 1.4 dB. To do the correction, check compression at 6 dB below that level (0 dBm). It is approximately 0.1 dB. The corrected compression is then the sum of these two dB ratios (1.4 + 0.1 = 1.5 dB). In the automated set-up described under Measurement Automation the plot in Figure 6 is corrected automatically by the program.

In either of these expressions for calculating compression, it is much more accurate to measure AM depth with the average detector in the 8901A Analyzer rather than the peak detector, because measuring AM depth with the peak detector can introduce significant errors if there is any over-shoot on the square-wave. See appendix for details.

Calculating Peak Input Level

Using the technique described here, compression is determined for the peak input level. Because the RF test signal is amplitude modulated, the peak input level into the mixer is greater than the CW output level set on the signal generator. Therefore, to determine the peak level of the RF test signal a correction factor is required. This correction factor is computed from

$$\triangle \text{ (dB)} = 20 \log (1 + M)$$

where M = reference AM depth in fractional form. See appendix for derivation.

For example, if the generator level is set at +10 dBm with square-wave AM of 33%, and the step attenuator is set at 5 dB, peak level (dBm) = +10 − 5 + 20 log (1 + M)
= 10 − 5 + 20 log (1 + .33)
= +7.48 dBm

For 33% AM depth the peak level is 2.48 dB higher than the average level.

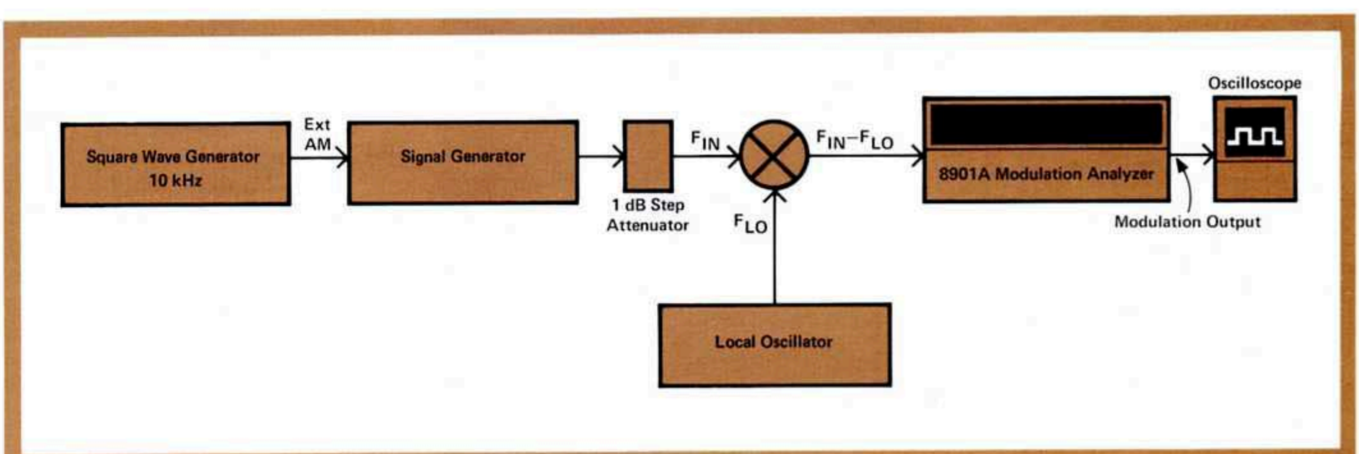

Figure 4. Setup for measuring Mixer Compression manually.

Measurement Automation

The outstanding performance of the 8901A Analyzer would be remarkable even if it were operated only in the manual mode but, with the added feature of programmability, it becomes an extremely powerful instrument. Under calculator control (HP-IB), the 8901A in an automated measurement setup can generate a large volume of accurate, comprehensive data in a very short time. In the typical test setup shown in Figure 5, the sensitivity of the 8901A Analyzer, enhanced by the versatility and speed of automation reveals unexpected responses in mixer behavior, some of which were previously undetected. These responses are illustrated in Figures 7 and 8. The plots in Figure 8 typify the compression characteristics of a "Classic" mixer and they reveal three interesting effects:

1. Varying LO level over a fairly wide range results in only a slight movement of the 1-dB compression point.
2. Holding the input level 10 dB below the LO level does not always insure operation well out of compression.
3. For a fixed input level, compression decreases as LO level increases.[1]

Another interesting aspect of mixer behavior is revealed by the plots of Figure 7: IF output "peaks" or "expands" before it compresses. Further, this peaking occurs at LO levels less than 10 dBm (evident here between −4 and +2 dBm.) This effect is explained by the fact that complete turn-on in mixer diodes does not occur at lower LO levels. As the input signal is increased, however, it causes the diodes to turn on more completely, which in turn reduces the conversion loss and causes the output to expand. *Distortion is caused by expansion as well as compression.*

The program used to obtain the data in Figures 7 and 8 is included in this application note. Two listings are provided, one for the HP 9825 controller and the other for

(1) Yell, R.W., "Signal-Compression Performance of Schottky Barrier Diodes in Microwave Mixers", IEEE Trans. July, 1969 pp 360-361.

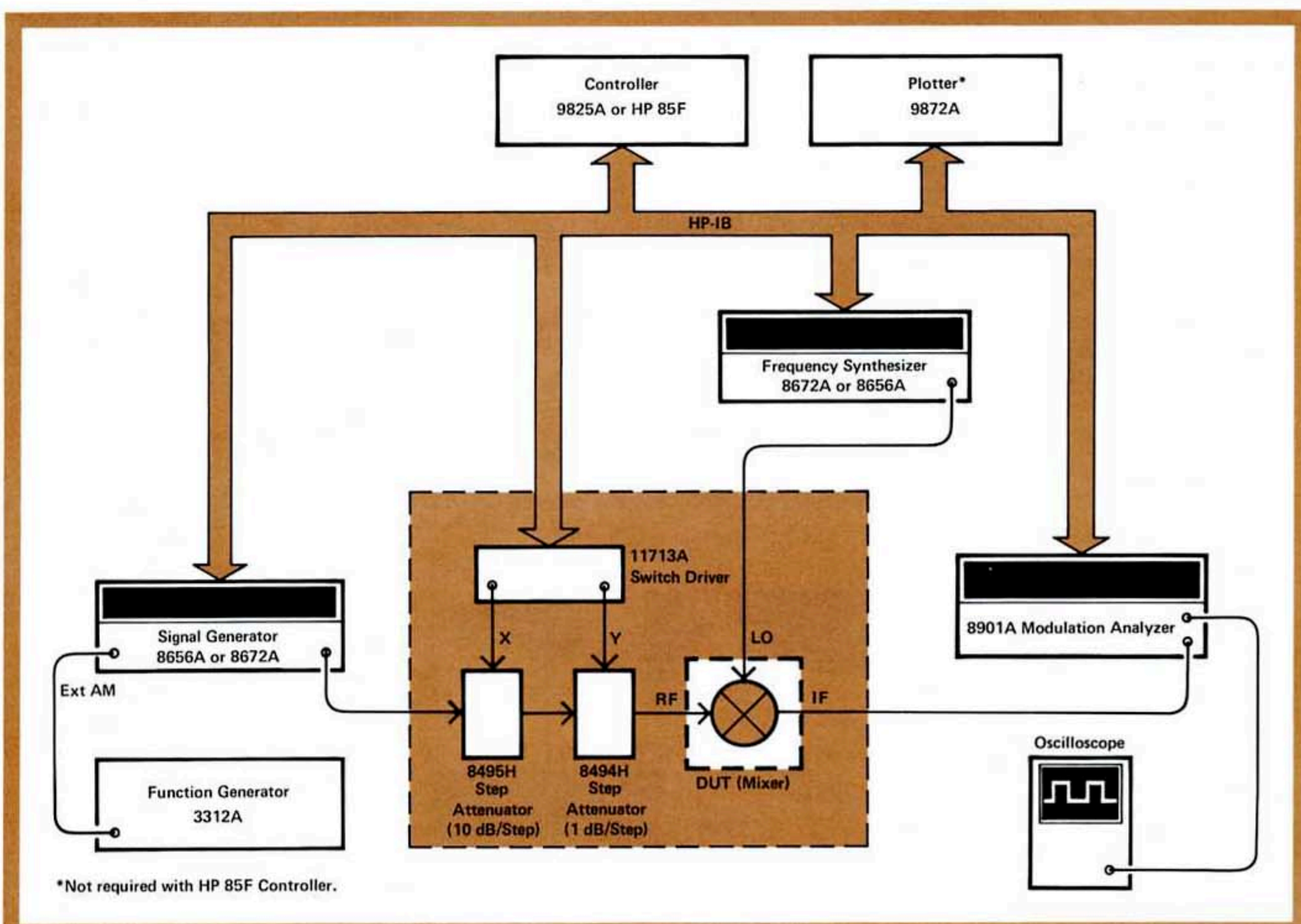

Figure 5. Setup for Automated Compression Measurement.

the HP85F controller. Each program automatically steps the signal level into the mixer, calculates the corresponding compression ratio at each level, and generates an accurate plot of compression versus peak input level for the device under test. The program also checks for lower-level compression (when $B \neq B'$) and allows varying both LO level and input signal level independently. The measurement setup in Figure 4 can easily be automated (Figure 5). Table 1 is a complete equipment list for the automated setup. A sample data printout for automatic compression measurement is shown in Figure 9.

Table 1. Equipment List for Automated Compression Measurement

Instrument	**Model Number**
Controller	HP 85F or HP 9825B/T and 98034A
Plotter	HP 9872A (not required with 85F)
Modulation Analyzer	HP 8901A
Signal Generator	HP 8656A or HP 8672A
Frequency Synthesizer	HP 8656A or HP 8672A
Function Generator	HP 3312A, or 3310A
Step Attenuators (Programmable)	HP 8495H (10 dB/step) HP 8494H (1 dB/step)
Attenuator/Switch Driver	HP 11713A

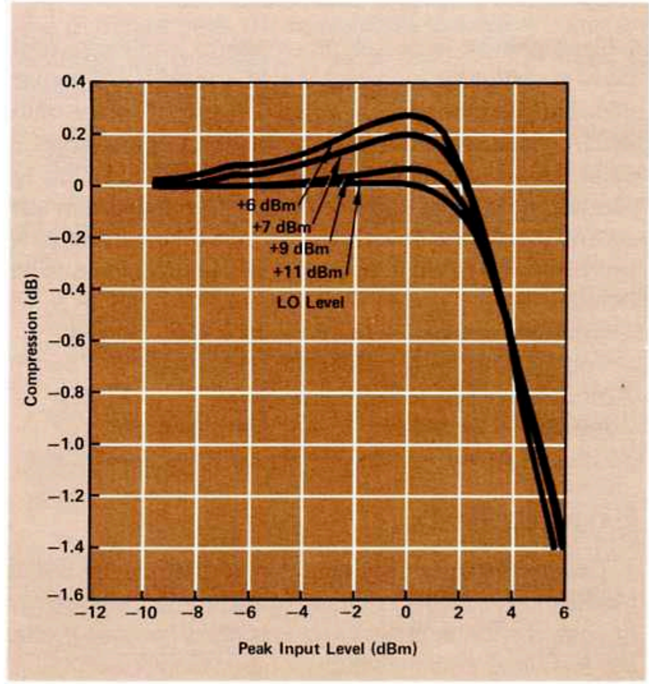

Figure 7. Compression vs. Peak Input Level at Various LO Levels for HP 10514A. (RF Signal Frequency 500 MHz.)

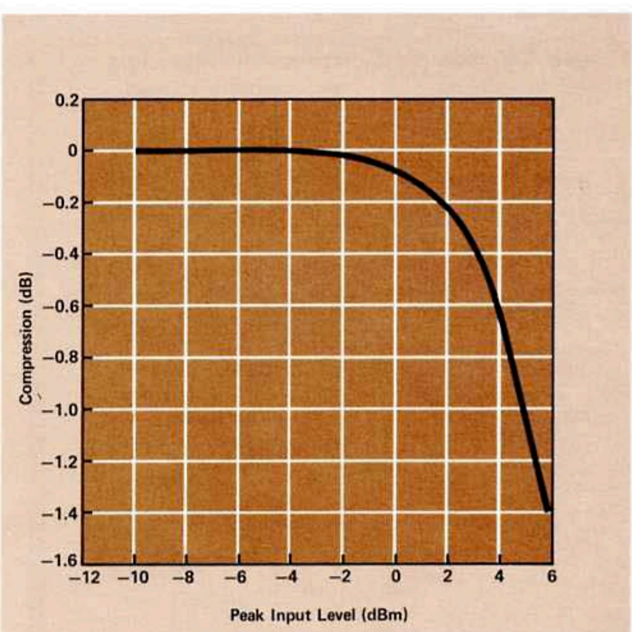

Figure 6. Sample Compression Curve.

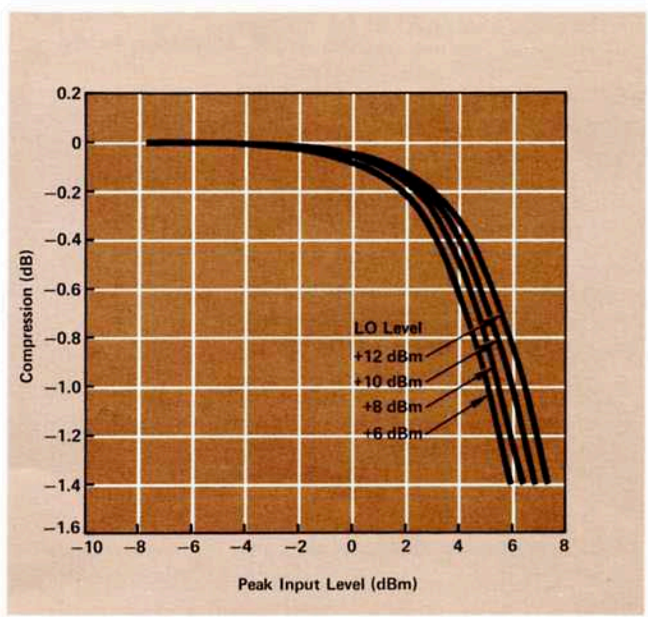

Figure 8. Compression vs. Peak Input Level at Various LO Levels for HMXR-5001. (RF Signal Frequency 4 GHz.)

Related Applications

Compression, especially in amplifiers, can cause other kinds of distortion such as AM/ϕM and AM/AM conversion. The extremely low residual ϕM and AM noise of the 8901A Analyzer enables it to measure these types of distortion accurately and conveniently. Although this application note deals with measuring compression in mixers and amplifiers, there are other related applications for which the 8901A is a powerful measurement aid. They include:

Frequency response in phase-lock loop circuits
Voltage-controlled-oscillator gain linearity
Modulator/AGC characterization
Amplitude Modulator linearity and gain.

Conclusion

This application note demonstrates that the HP 8901A Modulation Analyzer is ideally suited to the measurement of compression in mixers and amplifiers because it offers the following advantages over other techniques:

- Better than 1% overall measurement accuracy.
- Overall resolution of 0.01% resulting in the ability to detect smaller amounts of compression than possible with other methods.
- Insensitivity to system mismatches, a further contribution to overall accuracy.
- Permits monitoring the quality of the compressed signal with an oscilloscope, a very useful feature for mixer circuit designers.
- Allows measurement of other kinds of distortion caused by compression (AM/ϕM and AM/AM conversion, for example) at no additional cost.

8901A Mixer Compression Test

LO frequency= 4000.00MHz
LO drive level= 10.0dBm
IF frequency= 200.00MHz

Peak Input Level(dBm)	Compression(dB)
-9.56	0.00
-8.56	0.00
-7.56	-0.00
-6.56	-0.01
-5.56	-0.01
-4.56	-0.01
-3.56	-0.01
-2.56	-0.02
-1.56	-0.03
-0.56	-0.05
0.44	-0.07
1.44	-0.11
2.44	-0.17
3.44	-0.29
4.44	-0.49
5.44	-0.80
6.44	-1.21
7.44	-1.70
8.44	-2.26

Figure 9. Sample Compression Data Obtained with the Automated Setup Shown in Figure 5.

8901A MIXER COMPRESSION TEST

LO frequency= 4000 MHz
LO drive level= 10 dBm
IF frequency= 200 MHz

Peak input level(dBm)	Compression (dB)
-9.63	-0.00
-8.63	-0.00
-7.63	-0.01
-6.63	-0.01
-5.63	-0.01
-4.63	-0.02
-3.63	-0.03
-2.63	-0.04
-1.63	-0.05
-0.63	-0.09
0.37	-0.12
1.37	-0.17
2.37	-0.25
3.37	-0.38
4.37	-0.60
5.37	-0.90
6.37	-1.28
7.37	-1.69
8.37	-2.13

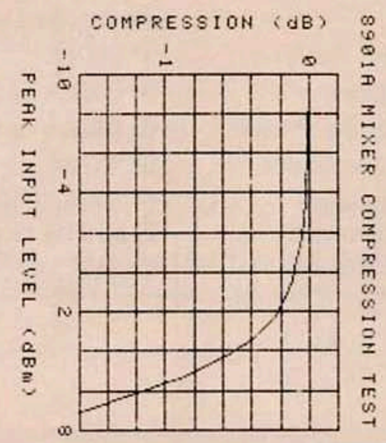

Figure 10. Sample Compression Data Obtained with HP85F Controller.

Appendix

Derivation of the Compression Formula

The 8901A measures AM depth according to the relation

$$M+ = \frac{E_{max} - E_{avg}}{E_{avg}}, \quad M- = \frac{E_{avg} - E_{min}}{E_{avg}} \qquad \text{(A-1)}$$

where M+ = positive peak of AM depth
M− = negative peak of AM depth

The 8901A Analyzer actually displays AM depth in percent (%) but all calculations are made using modulation index (i.e., fractional notation).

E_{max}, E_{min}, E_{avg} = maximum, minimum and average carrier levels.

For the square-wave modulating signal (Figure A-1) the duty cycle of both levels is 50%. Therefore, the average level is

$$E_{avg} = \frac{A + B}{2} \qquad \text{(A-2)}$$

where $A = E_{max}$ and $B = E_{min}$.

Substituting for E_{avg} in (A-1) for M_+ yields

$$M_+ = \frac{A - B}{A + B} \qquad \text{(A-3)}$$

Equation (A-3) relates the measured peak AM depth (M_+) to A and B. M_+ is the reference AM depth with no compression.

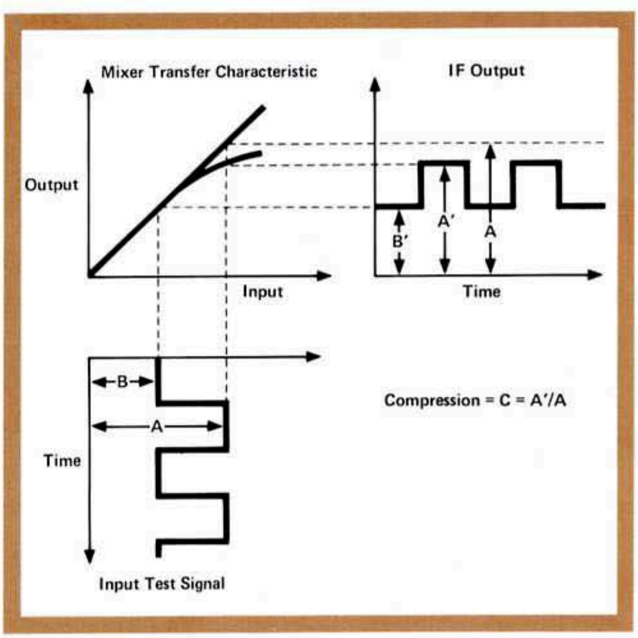

Figure A-1. Effects of Compression on Square-Wave Modulated RF Signal.

As the average level of the input test signal is increased, the IF output peak (A) compresses to level A′. This also changes the average IF output level. In this case, the measured positive peak AM depth (M′) is

$$M'_+ = \frac{A' - B'}{A' + B'} \qquad \text{(A-4)}$$

M'_+ in (A-4) is expressed in fractional form.

If the lower level (B) is not compressed then

$$B = B' \qquad \text{(A-5)}$$

By definition, the compression ratio (C) is

$$C = \frac{A'}{A} \qquad \text{(A-6)}$$

Substituting for A′ and B′ from (A-6) and (A-5) into (A-4) yields

$$M'_+ = \frac{(C \times A) - B}{(C \times A) + B} \qquad \text{(A-7)}$$

Solving for C yields

$$C = \frac{B}{A} \cdot \frac{1 + M'+}{1 - M'+} \qquad \text{(A-8)}$$

Solving (A-3) for $\frac{B}{A}$ yields

$$\frac{B}{A} = \frac{1 - M+}{1 + M+} \qquad \text{(A-9)}$$

Substituting (A-9) for $\frac{B}{A}$ in (A-8) yields

$$C = \left(\frac{1 - M+}{1 + M+}\right) \cdot \left(\frac{1 + M'+}{1 - M'+}\right) \qquad \text{(A-10)}$$

Equation (A-10) relates the compression ratio (C) to the measured reference peak AM depth (M_+) and the compressed peak AM depth (M'_+).

Using the Average Responding Detector

Formula (A-10) assumes that the AM depth is measured with the $PEAK_+$ detector. If the demodulated square-wave has any ringing or overshoot, the peak detector will cause significant errors in the measurement. Ringing due to the 8901A Analyzer is eliminated by selecting the internal 20 kHz low-pass filter. However, any ringing generated by the signal generator will still degrade the measurement. Therefore, the average detector is recommended. This detector is average responding but RMS calibrated for sinusoidal signals. The audio circuitry in the analyzer provides appropriate compensation for the difference in hardware gain. This gain is the ratio of the RMS to the average value of a sinewave and is equal to

$$G = \frac{1/\sqrt{2}}{2/\pi} = 1.11 \qquad \text{(A-11)}$$

Because the modulating signal is a square-wave the RMS value is the same as the average value. Therefore, square-wave measurements made with the average detector (M) are related to PEAK + measurement (M_+) by

$$M = \frac{M_+}{1.11} \qquad \text{(A-12)}$$

Correcting for M in (A-10) from (A-12) yields

$$C = \left(\frac{G - M}{G + M}\right) \cdot \left(\frac{G + M'}{G - M'}\right) \qquad \text{(A-13)}$$

where $G = 1.11$

The linear compression ratio in (A-13) can also be expressed in dB by

$$C_{(dB)} = 20 \log \left(\frac{G - M}{G + M}\right) \cdot \left(\frac{G + M'}{G - M'}\right) \qquad \text{(A-14)}$$

Derivation of correction for peak input level

$$\text{Modulation index} = M = \frac{A - B}{A + B} \qquad \text{(A-15)}$$

L = signal generator level (average level).

Since the square-wave is symmetrical

$$L = \frac{A + B}{2} \qquad \text{(A-16)}$$

Solving for B in (A-16) yields

$$B = 2L - A \qquad \text{(A-17)}$$

Solving for B in (A-15) yields

$$B = A \left(\frac{1 - M}{1 + M}\right) \qquad \text{(A-18)}$$

The ratio of the peak value (A) to the signal generator level (L) is $\frac{A}{L}$ which is also the correction factor.

Combining (A-17) and (A-18) and solving for $\frac{A}{L}$ yields

$$\frac{A}{L} = 1 + M \qquad \text{(A-19)}$$

$\therefore$ peak level (dB) = L + 20 log (1 + M) (A-20)

where L = signal generator level in dBm
M = modulation index in fractional form.

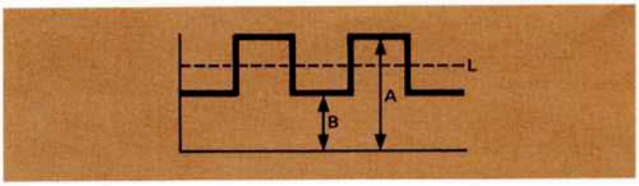

Figure A-2. Relationship of the peak input to average level.

Derivation of the expression which corrects for lower level (B) compression

The expression which corrects for lower level (B) compression, is

$$C_{cor} = C \cdot C'$$

If level B is compressed ($B \neq B'$)

$$\text{let } C' = \frac{B'}{B} \qquad \text{(A-21)}$$

By definition

$$C = \frac{A'}{A} \qquad \text{(A-22)}$$

From (A-4)

$$M' = \frac{A' - B'}{A' + B'}$$

Substituting for A′ and B′ from (A-21) and (A-22) and solving for $\frac{C}{C'}$ yields

$$\frac{C}{C'} = \frac{B}{A} \cdot \left(\frac{1 + M'}{1 - M'}\right) \qquad \text{(A-23)}$$

Substituting for $\frac{B}{A}$ from (A-9)

$$\frac{C}{C'} = \left(\frac{1 - M}{1 + M}\right) \cdot \left(\frac{1 + M'}{1 - M'}\right) \qquad \text{(A-24)}$$

The right side of equation (A-24) is the original compression (C), therefore, the corrected compression C_{cor} is

$$C_{cor} = C \cdot C' \text{ or}$$

$$C_{cor}\ (\text{dB}) = 20\,[\log C + \log C'] \qquad \text{(A-25)}$$

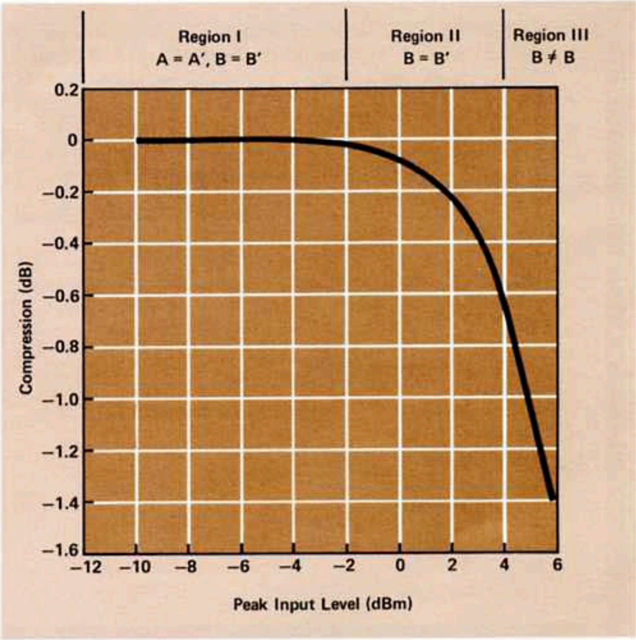

Figure A-3. Typical mixer compression curve with distinct compression regions.

Equation (A-25) is best explained by referring to Figure A-3. In this figure, the compression characteristic of a typical mixer is divided into three distinct regions.

In the first region, A = A′ and B = B′ and consequently the output of the mixer is not compressed. This is the reference output level.

In the second region, A ≠ A′ (level A is compressed), and B = B′ (level B is not compressed). This region begins at an input level which produces perceptible compression (less than 0.1 dB). It begins in Figure A-3 at −2 dBm input level. It ends at an input level which is 6 dB higher. Equation (A-13) is correct for this region.

In the third region, both levels A and B are compressed and consequently both contribute to the total compression. As indicated in Figure A-3, this occurs at compression ratios which are approximately 0.7 dB or greater. Equation (A-25) is correct for this region. This equation simply indicates that total compression is the sum of the two dB compression ratios. If equation (A-13) is used for this region the calculated compression will be less than the actual compression.

Measuring Compression for IF Up to 2.2 GHz

The highest frequency that the 8901A Analyzer can measure is 1300 MHz. However, using a harmonic mixing technique you can extend the measurement range of the analyzer up to 2.2 GHz without additional equipment. This technique uses the third harmonic of the local oscillator in the 8901A Analyzer. Just tune the 8901A 1 MHz lower than one-third of the frequency to be measured. For example, to measure AM on a 2100 MHz signal, manually tune the 8901A to

$$F_{tuned} = \frac{2100}{3} - 1 = 699 \text{ MHz.}$$

AM measurement accuracy is basically unaffected, but input sensitivity is decreased.

Mixer Compression Test Program for HP 9825 Controller

```
0: "8901A Mixer Test(repetitive LO)":
1: ent "Enter highest RF level",T;T-2}U
2: dev "Ma",714,"11713",728;dim A[U-18:U,2],A$[10]
3:
4: "Init":time 6000;rem 7;cli 7
5: wrt "Ma","clau6.1spd1h010p0c0r0m1t0"
6: cfg 2
7: gto "Start"
8:
9:
10: "8901A Device subroutines":
11: "Am":
12: fmt ;wrt "Ma","M1T3";red "Ma",p1
13: ret
14: "Cnt":
15: fmt ;wrt "Ma","M5AU7.1SP4.1SPT3";red "Ma",p1
16: wrt "Ma","AU";if (p1-9e9)/100=10;wrt "Ma","T3";red "Ma",p1
17: ret
18: "Det":
19: fmt "D",f1.0,;wrt "Ma",p1;if p2#0;wtb "Ma","D3"
20: ret
21: "Flt":
22: (p1>0)+(p1>50)}p3;(p2>0)+(p2>3)+(p2>15)}p4
23: fmt "H",f1.0,"L",f1.0;wrt "Ma",p3,p4
24: ret
25: "Mtf":
26: if p1=0;wtb "Ma","4.0sp";ret
27: fmt f10.5,"mz";wrt "Ma",p1
28: ret
29: "Red":
30: fmt ;wrt "Ma","t3";red "Ma",p1
31: ret
32:
33: "11713 device subroutines":
34: "Att":(min(81,max(0,int(p1)))}p3)-10(-((int(p3/10)}p2)>11)+p2}p2)}p3
35: cll 'Swt#7'(p2,1,p4,p5);cll 'Swt#'(p3,5,p4,p5);cll 'Swset'(p4,p5);ret
36: "Swset":fmt b,f.0,z
37: if p1;wrt "11713",65,p1
38: if p2;wrt "11713",66,p2
39: ret
40: "Swt#":p1+4(p1>3)}p5;gto +2
41: "Swt#7":p1}p5
42: if bit(p6,p5);p2+p6+10p3}p3;gto +2
43: p2+p6+10p4}p4
44: gto -2;if (p6+1}p6)>=4;ret
45:
46:
47: "Start":
48:
```

Mixer Compression Test Program (continued)

```
49: "Variable explanation":
50: "I is RF level in dBm":
51: "D is LO drive level":
52: "U is reference sig-gen level":
53: "A is the 11713A attenuation":
54: "T is peak RF level from sig gen":
55: "P is printer select code":6}P
56: "G is average detector correction factor":1.11}G
57:
58: "Enter data":
59: fmt /,12x,"8901A Mixer Compression Test",2/;wrt P
60: ent "Enter LO frequency(MHz)",L
61: ent "Enter LO drive level(dBm)",D
62: ent "Enter IF frequency(MHz)",X
63: fmt "Set RF sig gen to",f4.1,"dBm";wrt 0,U;stp
64: fmt "Set to",f8.2,"MHz, 33% Ext AM";wrt 0,L-X;stp
65: fmt "LO frequency= ",f8.2,"MHz";wrt P,L
66: fmt "LO drive level=",f7.1,"dBm";wrt P,D
67: fmt "IF frequency= ",f8.2,"MHz",/;wrt P,X
68:
69: "Get reference at -15dBm":
70: cll 'Att'(U+15)
71: cll 'Mtf'(X);cll 'Flt'(0,20)
72: wtb "Ma","dlt0";dsp "Adjust function gen. for 33%";stp
73: dsp "Getting reference . . ."
74: "Select average detector":cll 'Det'(4)
75: 0}Z;cll 'Am'(R)
76: "Average 3 readings":
77: for I=1 to 3;cll 'Red'(R);Z+R}Z;next I
78: .01*Z/3}R;dsp
79:
80:
81: "Compression Measurement":
82: fmt 5x,"Peak Input Level(dBm)",5x,"Compression(dB)",/;wrt P
83:
84: "Measurement loop":
85: for I=U-18 to U
86: cll 'Att'(U-I)
87: cll 'Red'(S);.01*S}S
88: "Compute compression":
89: (G-R)*(G+S)/((G+R)*(G-S))}C
90: "Convert compression to dB":
91: 20log(C)}F}A[I,2]
92: "Secondary correction":if I>=U-12;20log(C)+A[I-6,2]}F}A[I,2]
93: "Compute peak input level":
94: I+20log(1+R/G)}J}A[I,1]
95: "Print result":fmt 12x,f6.2,15x,f7.2;wrt P,J,F
96: next I
97:
98: fmt 2/;wrt P
99:
100:
101: "Plot results":
102: ent "Plot results?(y or n)",A$
103: if pos("N",cap(A$))#0;gto "Start"
104: if flg2;gto "Plot data"
105: "Plot axes":sfg 2
106: psc 705;pclr;pen# 1
107: scl U-26,U+6,-2.5,2
108: fxd 0;xax -1.6,1,U-16,U+2,2
109: fxd 1;yax U-16,.1,-1.6,.2,2
110: "Draw graph lines":
111: line 2,1
112: for I=.2 to -1.4 by -.2
113: plt U-16,I,1;plt U+2,I,2
114: next I
115: for I=U-14 to U+2 by 2
116: plt I,.2,1;plt I,-1.6,2
117: next I
118: "Labels":
119: csiz 2;plt U-15,.4,1;lbl "8901A Mixer Compression Test"
120: plt U-13,-1.95,1;lbl "Peak Input Level(dBm)"
121: csiz 2,1.5,1,90;plt U-19,-1.2,1;lbl "Compression(dB)"
122:
123: "Plot data":lim U-16,U+2,-1.4,.2;line
124: pen# 3
125: for I=U-16 to U
126: plt A[I,1],A[I,2]
127: next I
128: pclr;pen# ;plt 4,2,1;gto "Start"
129: end
*4534
```

Mixer Compression Test Program for HP 85F Controller

```
10 ! *************************
20 !                         *
30 ! 8901A MIXER COMPRESSION *
40 ! TEST PROGRAM            *
50 !                         *
60 ! *************************
70 !
80 GOTO 5000 ! START OF PROGRAM
90 !
100 ! ************************
110 !                        *
120 ! SUBROUTINE DIRECTORY   *
130 !                        *
140 ! ************************
150 !
199 !
200 ! 8901A ******************
210 ! 2100 AM
220 ! 2200 TUNE
240 ! 2400 DETECTOR
250 ! 2500 FILTERS
280 ! 2800 DATA
299 !
300 ! 11713A *****************
310 ! 3100 ATTEN 0-81 dB
399 !
400 ! SYSTEM *****************
410 ! 4100 INITIALIZE
420 !
430 !
999 IMAGE K

2000 ! 8901A INST SUBS ********
2010 !
2100 ! AM(A),%
2110 OUTPUT 714 USING 999 ; "M1T
     3"
2120 ENTER 714 ; A
2130 RETURN
2199 !
2200 ! TUNE(A),MHz
2210 IF A=0 THEN OUTPUT 714 USIN
     G 999 ; "4.0SP"
2220 IMAGE 4D.5D,"MZ"
2230 OUTPUT 714 USING 2220 ; A
2240 RETURN
2250 !
2400 ! DET(A,B)
2410 IMAGE "D",D
2420 OUTPUT 714 USING 2410 ; A
2430 IF B=0 THEN RETURN
2440 OUTPUT 714 ;"D3"
2450 RETURN
2499 !
2500 ! FLT(A,B)
2510 A1=(A>0)+(A>50)
2520 B1=(B>0)+(B>3)+(B>15)
2530 IMAGE "H",D,"L",D
2540 OUTPUT 714 USING 2530 ; A1,
     B1
2550 RETURN
2599 !
2800 ! DATA(A)
2810 OUTPUT 714 USING 999 ; "T3"
2820 ENTER 714 ; A
2830 RETURN
2899 !

3000 ! 11713A INST SUBS *******
3010 !
3100 ! ATTEN 0-81 dB (A)
3110 A1=MIN(81,MAX(0,IP(A)))
3120 A2=IP(A1/10)
3130 IF A2>7 THEN A2=7
3140 A1=A1-10*A2
3150 A3=5 @ S1=0 @ S0=0
3160 GOSUB 3200 ! SWITCHES 1dB
3170 A1=A2 @ A3=1
3180 GOSUB 3220 ! SWITCHES 10dB
3190 GOSUB 3300 ! SW SET
3195 RETURN
3199 !
3200 ! SWITCHES
3210 IF A1>3 THEN A1=A1+4
3220 FOR A4=0 TO 3
3230 IF BIT(A1,A4) THEN S1=A3+A4
     +10*S1 ELSE S0=A3+A4+10*S0
3240 NEXT A4
3250 RETURN
3299 !
3300 ! SW SET
3310 IMAGE #,B,K
3320 IF S1 THEN OUTPUT 728 USING
      3310 ; 65,S1
3330 IF S0 THEN OUTPUT 728 USING
      3310 ; 66,S0
3340 RETURN
3399 !

4000 ! SYSTEM SUBS ************
4010 !
4100 ! INITIALIZE
4110 SET TIMEOUT 7;6000
4120 REMOTE 7
4130 ABORTIO 7
4140 OUTPUT 714 USING 999 ; "CLA
     U 6.1SP 2.1SP D1 H0 L0 P0 C
     0 R0 M1 T0"
4150 OUTPUT 728 USING 999 ; "A12
     345678"
4160 RETURN
4170 !
4180 !

5000 ! ************************
5010 !                        *
5020 ! MAIN PROGRAM           *
5030 !                        *
5040 ! ************************
5050 !
5060 GOSUB 4100 ! INIT
5070 P=0 ! AXES PLOT FLAG
5080 DIM A(18,2)
5090 !
5100 ! VARIABLE EXPLANATION:
5110 ! I is RF level in dBm
5120 ! D is LO drive level
5130 ! U is reference sig gen
5140 !    level
5150 ! T is peak RF level
5160 ! G is average detector
5170 !    correction factor:
5180 G=1.11
5190 !
5199 !
```

Mixer Compression Test Program (continued)

```
5200 ! DATA ENTRY *************
5210 CLEAR
5220 DISP "Highest RF level (dBm
     )";
5230 INPUT T
5240 DISP "LO frequency (MHz)";
5250 INPUT L
5260 DISP "LO drive level (dBm)"
     ;
5270 INPUT D
5280 DISP "IF frequency (MHz)";
5290 INPUT X
5300 ! SET UP SIG GEN *********
5310 CLEAR
5320 DISP "*** Set RF sig gen to
     ";T-2;"dBm"
5330 BEEP @ PAUSE
5340 DISP "*** Set to";L-X;"MHz,
      33% Ext AM"
5350 BEEP @ PAUSE
5360 !
5370 U=T-2
5380 !


5400 ! HEADING ***************
5410 !
5420 CLEAR
5430 IMAGE ///"8901A MIXER COMPR
     ESSION TEST"//
5440 PRINT USING 5430
5450 PRINT "LO frequency=";L;"MH
     z"
5460 PRINT "LO drive level=";D;"
     dBm"
5470 PRINT "IF frequency=";X;"MH
     z"
5480 !
5490 !


5500 ! GET REFERENCE AT -15 dBm
5510 !
5520 A=U+15 ! ATTENUATION
5530 GOSUB 3100 ! ATTEN
5540 A=X ! IF FREQ
5550 GOSUB 2200 ! 8901A TUNE
5560 A=0 ! HP FILT
5570 B=20 ! kHz LP FILT
5580 GOSUB 2500 ! FILTERS
5590 ! 8901A: FREE RUN,PEAK DET
5600 OUTPUT 714 USING 999 ; "D1T
     0"
5610 CLEAR @ DISP "*** Adjust fu
     nction generator";"     for
     33% AM"
5620 BEEP @ PAUSE
5630 CLEAR @ DISP "Getting refer
     ence . . ."
5640 A=4 @ B=0 ! AVG DETECTOR
5650 GOSUB 2400 ! DET
5660 Z=0
5670 ! AVERAGE 3 READINGS:
5680 FOR I=1 TO 3
5690 GOSUB 2800 ! DATA
5700 Z=Z+A ! SUM
5710 NEXT I
5720 ! REFERENCE
5730 R=.01*Z/3
5740 CLEAR
5750 !
5760 !

5800 ! COMPRESSION MEASUREMENT
5810 !
5820 IMAGE //"Peak input";6X,"Co
     mpression"/"level(dBm)",9X,
     "(dB)"//
5830 PRINT USING 5820
5840 !
5850 !
5860 ! MEASUREMENT LOOP
5870 !
5880 FOR I=0 TO 18
5890 A=18-I ! ATTEN
5900 GOSUB 3100 ! ATTEN
5910 GOSUB 2800 ! DATA
5920 S=.01*A
5930 ! COMPUTE COMPRESSION:
5940 C=(G-R)*(G+S)/((G+R)*(G-S))
5950 ! CONVERT TO dB:
5960 F=20*LGT(C)
5970 ! SECONDARY CORRECTION:
5980 IF I>=6 THEN F=F+A(I-6,1)
5990 A(I,1)=F
6000 ! PEAK INPUT LEVEL:
6010 J=I+U-18+20*LGT(1+R/G)
6020 A(I,0)=J
6030 ! PRINT RESULT:
6040 IMAGE XX,DDZ.DD,8X,3DZ.DD
6050 PRINT USING 6040 ; J,F
6060 NEXT I
6070 !
6080 !
6090 !

6100 PRINT @ PRINT
6110 !
6120 !
6130 ! PLOT RESULTS
6140 !
6150 CLEAR @ DISP "Plot results(
     y/n)";
6160 INPUT A$
6170 IF POS("N",UPC$(A$)) THEN 5
     240 ! NEW MEASUREMENT
6180 IF P THEN 6400 ELSE 6200
6190 !
6200 ! PLOT AXES
6210 P=1
6220 GCLEAR @ GRAPH @ PEN 1 @ LD
     IR 0
6230 SCALE -24,0,-2,.5
6240 MOVE -22.9,.35 @ LABEL "890
     1A MIXER COMPRESSION TEST"
6250 FOR X=-20 TO -2 STEP 2
6260 YAXIS X,0,-1.6,.2
6270 NEXT X
6280 FOR Y=-1.6 TO .2 STEP .2
6290 XAXIS Y,0,-20,-2
6300 NEXT Y
6310 MOVE -20,-2 @ LABEL "PEAK I
     NPUT LEVEL (dBm)"
6320 FOR X=-20 TO -2 STEP 6
6330 MOVE X-(X<-4-U)-.2,-1.75 @
     LABEL VAL$(X+4+U)
6340 NEXT X
6350 MOVE -20.8,-.05 @ LABEL "0"
6360 MOVE -21.5,-1.05 @ LABEL "-
     1"
6370 LDIR 90
6380 MOVE -22.2,-1.5 @ LABEL "CO
     MPRESSION (dB)"
6390 !
6400 ! PLOT DATA
6410 FOR I=0 TO 18
6420 PLOT A(I,0)-U-4,A(I,1)
6430 NEXT I
6440 PENUP
6450 BEEP @ PAUSE
6460 CLEAR @ GOTO 5240 ! NEW MEA
     S
9999 END
```

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