Errata

Document Title: Harmonic Mixing with the HSCH-5500 Series Dual Diode (AN 991)

Part Number: 5953-4492E

Revision Date: June 1984

HP References in this Application Note

This application note may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this application note copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

About this Application Note

We’ve added this application note to the Agilent website in an effort to help you support your product. This manual provides the best information we could find. It may be incomplete or contain dated information, and the scan quality may not be ideal. If we find a better copy in the future, we will add it to the Agilent website.

Support for Your Product

Agilent no longer sells or supports this product. You will find any other available product information on the Agilent website:

www.agilent.com

Search for the model number of this product, and the resulting product page will guide you to any available information. Our service centers may be able to perform calibration if no repair parts are needed, but no other support from Agilent is available.
Harmonic Mixing with the HSCH-5500 Series Dual Diode

Application Note 991

**Introduction**

The difficulty of generating local oscillator power at higher frequencies has stimulated interest in conversion with subharmonic local oscillators for nearly forty years [1]. Earlier designs were inefficient because so much of the signal power was used to generate the unwanted fundamental mixing product. Harmonic mixing conversion loss was 3 to 5 dB worse than fundamental mixing conversion loss.

**The Antiparallel Pair**

Within the past decade this problem was solved with an improved circuit which does not allow fundamental mixing, the antiparallel pair [2, 3]. This circuit has the additional advantage of suppressing local oscillator noise and all even order mixing products. However, the degree of suppression of these unwanted products is related to the matching of the diode pair.

**The Monolithic Antiparallel Pair**

Adjacent diodes on a wafer are nearly identical electrically. However, it is difficult to separate diodes while maintaining knowledge of each diode’s position on the wafer. This problem is solved by making the diodes as monolithic pairs with a cathode-anode connection that remains when the wafer is separated. Figure 1 shows a Schottky pair with the capacitance of each diode less than 0.10 pF. Capacitance difference is less than 0.02 pF. Figure 2 shows the diode dimensions. This

![Figure 1](image1.png)

![Figure 2](image2.png)
A monolithic pair is available in the medium barrier version as HSCH-5510 as well as the low barrier HSCH-5531.

**Coplanar Waveguide**

The linear arrangement of the dual diode requires a transmission line with symmetrical ground planes on either side of the main line. The coplanar waveguide transmission line satisfies this requirement. Figure 3 shows the coplanar waveguide structure. The characteristic impedance is determined by the dielectric constant of the substrate and the ratio of \( b \) to \( a \). Figure 4 shows how the dimensions can be chosen to fit the dimensions of the dual diode.

**Diode Equivalent Circuit**

Figure 5 shows the diode equivalent circuit. The element values are chosen to match the measured impedance with one milliampere rectified current in each diode. This corresponds to approximately one milliwatt of local oscillator power. Best conversion loss was seen at higher power. This caused a slight shift in frequency from the design value.

Figure 6 is the computer analysis of diode impedance at the design signal frequency of 34 GHz and the local oscillator frequency of 17 GHz.

**Mixer Circuit**

Figure 7 shows the mixer circuit on coplanar waveguide (CPW). The 34 GHz matching circuit is on the left, the 17 GHz circuit on the right. A series shorted line on the left side of the diodes is a quarter wave long at the local oscillator frequency. This decouples the signal tuning circuit from the local oscillator circuit. Similarly, a
series shorted line a quarter wave long at the signal frequency decouples the local oscillator tuning circuit from the signal circuit.

Although shunt elements can be used in CPW they require bond wires to maintain equal potential across breaks in the ground plane [4]. A simpler matching circuit uses two series transmission lines [5]. Figure 8 shows the transmission line impedance values from reference 5.

**Signal Frequency Tuning**
The diode is matched with a 33 ohm line which resonates the diode impedance and a quarter wave 96 ohm transformer to complete the match. Figure 9 shows the path on the Smith Chart.

It is theoretically possible to match the diode with a single transmission line [6], but the characteristic impedance is 17 ohms. The lowest reasonable impedance is about 30 ohms. Lower values require line spacings less than 0.001 inch.

**Local Oscillator Frequency Tuning**
Figure 10 shows the tuning on the local oscillator side of the diodes. The series stub adds 38.5 ohms of inductance to the impedance of the diodes. A 33 ohm line then resonates the circuit. A quarter wave 74.5 ohm line completes the matching. The single line replacing these two lines would require a 19 ohm characteristic impedance.

**Computer Analysis**
Figure 11 shows the computer analysis of the complete circuit [7]. The quarter wave series lines produce unity $S_{11}$ at 17 GHz and
The indicated reflection coefficients correspond to 2 dB reflection loss at 33 and 35 GHz.

**Measured Performance**

Mixer conversion loss was measured in the circuit shown in Figure 12. Output frequency was 13 MHz. Frequency and L.O. power were varied to find the optimum operating point of 33.8 GHz. Optimum L.O. power was +3 dBm for the low barrier HSCH-5530 and +6 dBm for the medium barrier HSCH-5510. Figure 13 shows how conversion loss varies with local oscillator power. The medium barrier diode is slightly more sensitive at optimum power level but the low barrier diode is more tolerant of variations in local oscillator power level. At one milliwatt the low barrier diode is degraded about 1 dB while the medium barrier diode is degraded more than 10 dB.

Figure 14 shows the frequency performance of the medium barrier mixer. The curve for the low barrier version is similar. The dashed line is the computed mismatch loss normalized to the optimum conversion loss. The area near the design frequency correlates quite well, but the measured nulls and peaks do not appear in the computed data. These may be related to parasitic elements not considered in the analysis.

Compression characteristics for the low barrier diode are shown in Figure 15. When the optimum L.O. power for low level is used the 1 dB compression is seen at -5 dBm input and the output peaks at -13 dBm with +1 dBm input. With local oscillator power increased to
13 dBm compression is seen at +2 dBm input and the output peaks at -7.5 dBm with +7 dBm input.

Similar data for the medium barrier mixer in Figure 16 shows a 2 or 3 dB higher level of compression and saturation with optimum L.O. power. At the higher L.O. power level there is little difference between the two diodes.

The 4 x 2 and 6 x 3 mixing products were seen with conversion loss exceeding 55 dB and 60 dB respectively.

Summary
A monolithic Schottky diode pair on coplanar waveguide is well suited to the design of an antiparallel pair harmonic mixer. Measured conversion loss is 8 dB at a signal frequency of 33.8 GHz. This is comparable to the loss for fundamental mixing.

Notes:
7. Compact Software, Inc. Palo Alto, CA
www.hp.com/go/rf
For technical assistance or the location of your nearest Hewlett-Packard sales office, distributor or representative call:

**Americas/Canada:** 1-800-235-0312 or (408) 654-8675

**Far East/Australasia:** Call your local HP sales office.

**Japan:** (81 3) 3335-8152

**Europe:** Call your local HP sales office.

Data Subject to Change

Copyright © 1984 Hewlett-Packard Co.
Printed in U.S.A. 5953-4492E (6/84)