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UNBIASED, SUB-HARMONIC MIXERS FOR MILLIMETER WAVE SPECTRUM ANALYZERS

R.J. Matreci, F.K. David
Signal Analysis Division
Hewlett-Packard Company
1424 Fountain Grove Parkway
Santa Rosa, California 95401

SUMMARY

Even harmonic mixers with vastly improved sensitivity and flatness are described for the 18 to 60 GHz bands. Using GaAs antiparallel-pair diodes, conversion loss of 19, 21 and 23 dB is achieved for the 6th, 8th and 10th harmonic respectively of the analyzer's local oscillator.

A Proper MMW Spectrum Analyzer Mixer

To extend the frequency range of a microwave spectrum analyzer to 60 GHz and beyond, an external waveguide mixer must perform a high order multiplication of the instrument's local oscillator which has a typical range of 2.5 to 6.5 GHz. These "front ends" are non-preselected at this time awaiting further development of wide band tunable resonators for the millimeter wavelengths. With no preselection, it is up to the host instrument to identify the multiple harmonic responses. However, this should be the only trade off in performance; amplitude calibration, flatness and conversion loss should approach or equal that of the coaxial inputs below 20 GHz. In addition, if there are no electrical or mechanical adjustments to be made as a function of frequency, e.g. bias current or backshorts, wideband and automated spectral measurements are possible. Reasonably high burnout level and physical ruggedness are required for reliability.

Even Harmonic Mixer Design

A set of three waveguide mixers has been designed covering bands from 18 to 60 GHz; fig. 1 is the U-band (40-60 GHz) version. In the schematic of Fig. 2, a microstrip diplexer combines the LO from and the IF to the spectrum analyzer onto a single path thru the 6.3 GHz LPF to the diodes. The RF signal enters via a tapered waveguide section which is terminated by the diodes. The antiparallel-pair diode configuration [1], while not LO-RF balanced, provides reverse voltage breakdown protection for each diode and improved conversion loss over single diode circuits since the conductance waveform symmetry produces only even harmonics of the LO; i.e. less energy is lost to unused harmonics. The diodes, Fig. 3, are a monolithic GaAs pair [2] with a 250 micron diameter loop in which the even order conductance harmonics are contained. Zero bias capacitance is 13 fF per diode and series resistance is 17 ohms. A polyimid layer passivates the diodes and contributes to the excellent beam pull strength of 25 grams.

A key factor in producing an unbiased, harmonic mixer with flat conversion loss versus frequency is the control of the odd harmonics of the LO that are produced across the diodes. Although the conductance waveform g(t), Fig. 2, contains only even harmonics of the LO, which remain inside the loop, the input current $i_d(t)$ contains only odd harmonics.

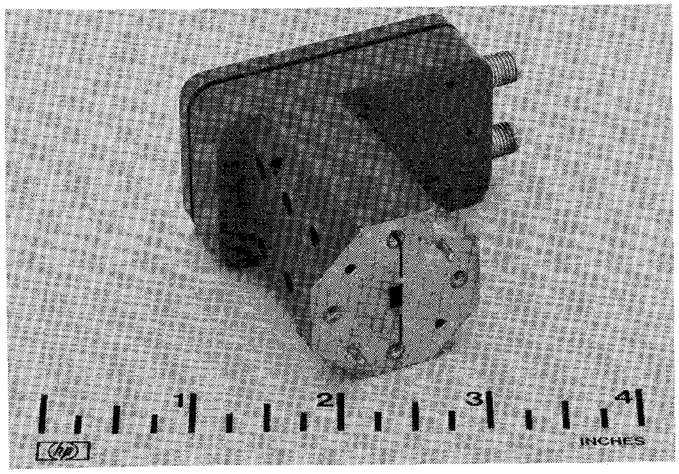

FIGURE 1. U-BAND (40-60 GHz) 10th HARMONIC MIXER.

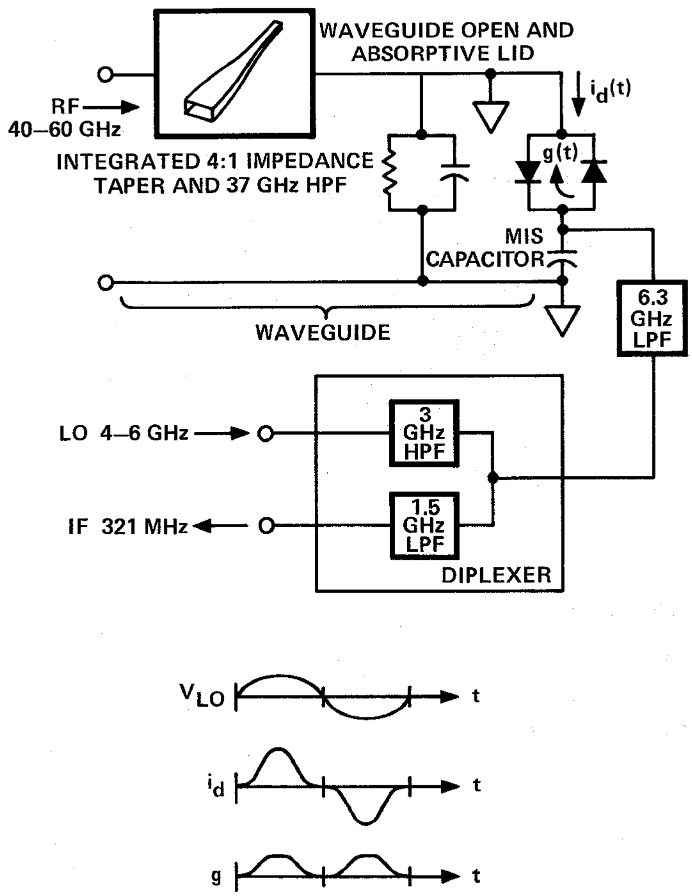

FIGURE 2. U-BAND (40-60 GHz) 10th HARMONIC MIXER SCHEMATIC.

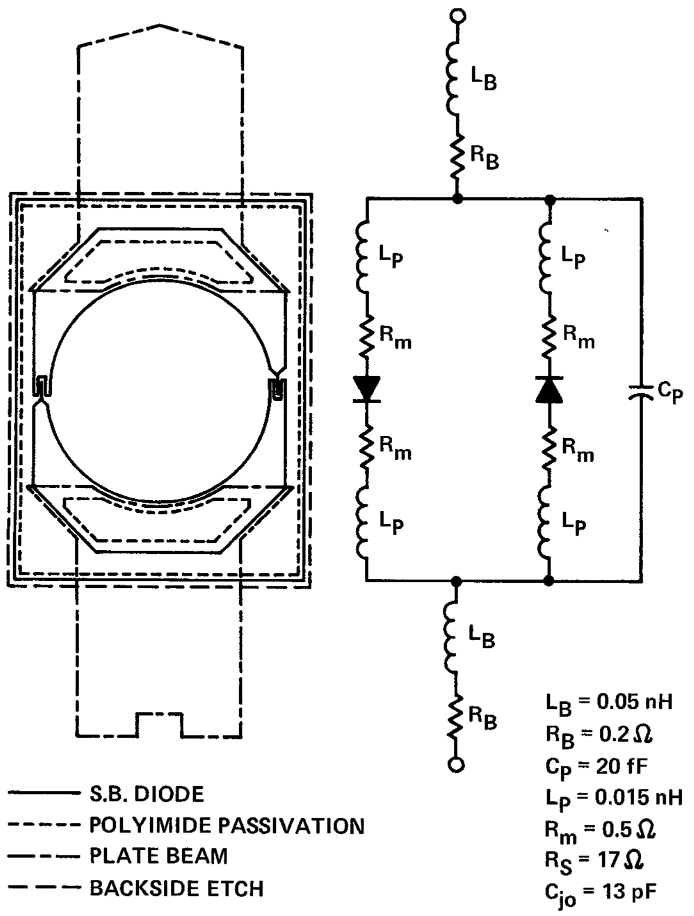

FIGURE 3. GaAs ANTIPARALLED PAIR DIODE AND EQUIVALENT CIRCUIT.

If these odd harmonics propagate away from the diode's location and then reflect back from any element internal or external to the mixer, the desired even harmonic could be severly weakened by proper phasing of new constructions of this harmonic due to these re-entering signals. For example, a reflected 5th harmonic is efficiently doubled to the 10th yielding a new 10th harmonic component that has nearly the same amplitude level as the 10th created directly from the LO's fundamental.

In previous harmonic mixers, these destructive interference effects lead to numerous, large, spike-like increases of conversion loss versus frequency; a change in bias current or backshort position is required to move the reconstruction phase away from cancellation.

For these mixers, odd harmonic reflections from the diplexer and the LO source systems are eliminated by the short produced at the diodes by the lumped first element of the 6.3 GHz LPF. This metal-insulator-semiconductor capacitor is also in series with the RF signal and thus must maintain its short throughout the RF band so the entire RF voltage will appear across the diode. The capacitor dimensions are 75 X 75 microns and SiO_2 dielectric layer thickness is 4,400 A pushing the self resonance to beyond 75 GHz.

The waveguide highpass filter follows a symmetrical exponential-to-cosine-cubed taper [3], and prevents odd harmonics from reflecting off the out-of-band source match of the signal system being measured. Especially troublesome are components such as bends, twists, and even the terminated arm of directional couplers, all of which present significant reflections at or below cutoff.

The high pass filter's width taper is integrated into a modified expontential waveguide height taper [4] which in a minimum of length lowers the guide impedance by a factor of 4 to match the time-average impedance of the diodes. The diodes are thermosonically bonded across this reduced height waveguide opening (.5mm), one terminal to the bottom wall, the other onto the MIS capacitor which is epoxied to the top wall opening.

Early on, a rectangular-to-double-ridged taper was tried, but the large variation in cutoff frequency along the taper was itself a source of odd harmonic reflection!

The relatively large local oscillator drive level required (+14 dBm min.) is a result of the high diode barrier height (Vf @ 1 mA = .79V) and the need for a large conduction angle. From Fig. 4, only angles above 140 degrees will avoid nulls in the 8th or 10th harmonic of the conductance waveform.

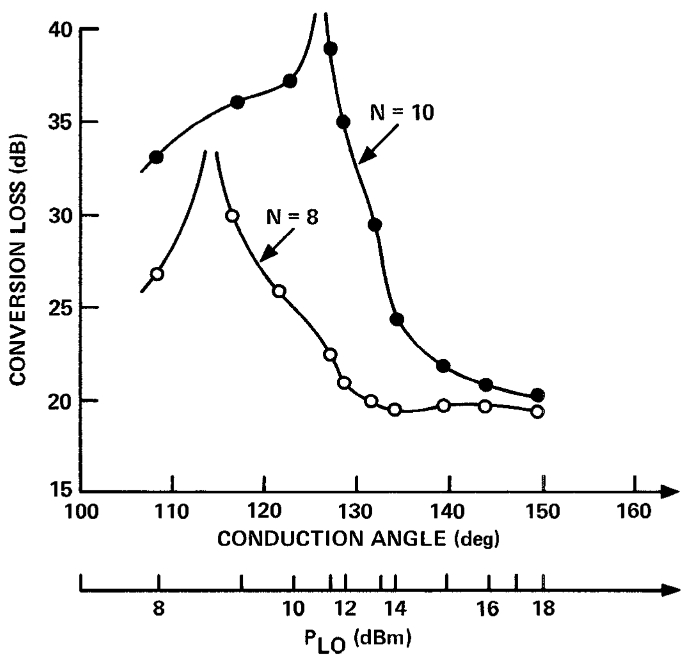

FIGURE 4. MEASURED CONVERSION LOSS VS LOCAL OSC. POWER & COMPUTED CONDUCTION ANGLE.

Performance Measurements

Conversion loss for each waveguide band from 18 to 60 GHz is shown in Fig. 5. To demonstrate the improved flatness and sensitivity of the unbiased mixers, the performance of a biased mixer (HP11517A) is also plotted for the cases of bias optimized at 30 GHz then fixed, and bias optimized at each frequency across the 26.5 - 40 GHz band. Return loss of the RF port exceeds 11 dB (VSWR less than 1.8:1) for each band. The return loss measurement is an example of the mixer making a difficult measurement. Those in-band odd harmonics that are above the cutoff of the highpass filter will propagate from the mixer's waveguide port and would affect the measurement of returned signal if a wideband detector was used. Here the measurement was made with a second mixer and mainframe spectrum analyzer tracking the reflections of the swept incident RF signal.

Conclusion

High harmonic number waveguide mixers with improved performance have been achieved with an antiparallel-pair diode and careful containment of the generated harmonics.

Acknowledgement

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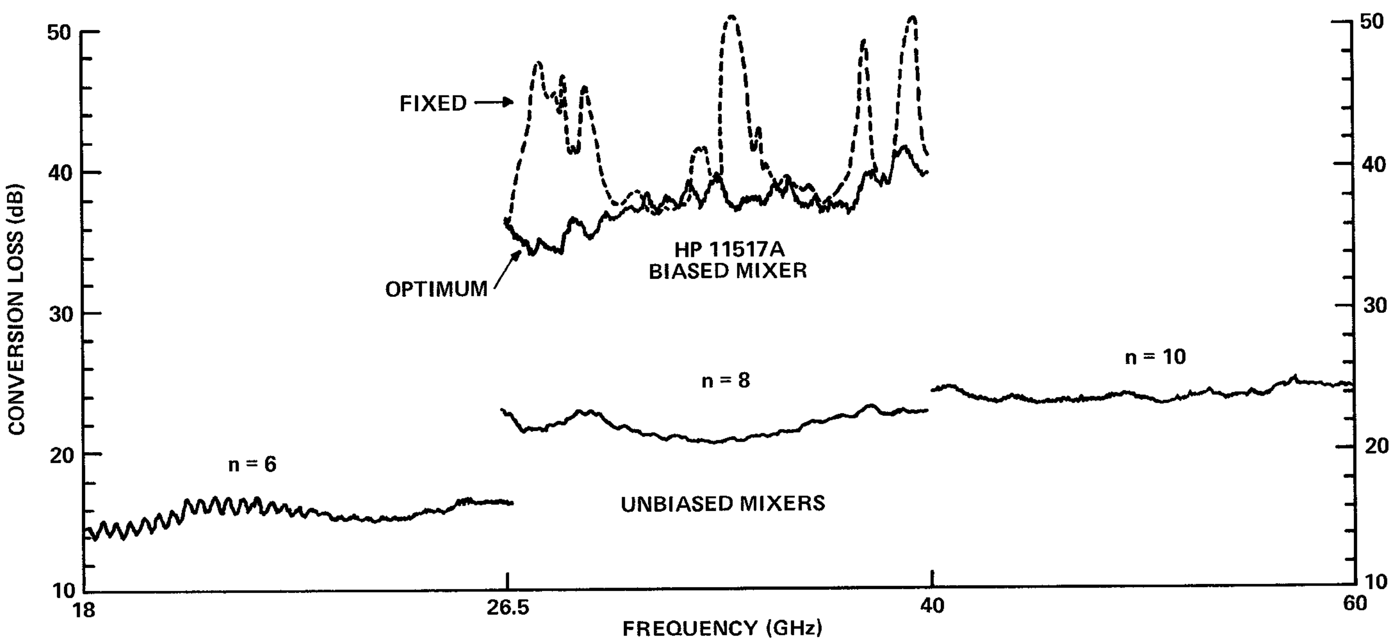

FIGURE 5. CONVERSION LOSS VS FREQUENCY FOR THREE BANDS. PLO = +14 dBm. SINGLE DIODE BIASED MIXED SHOWN FOR BIAS OPTIMIZED AT EACH FREQUENCY AND BIAS FIXED AT 3.5 mA.