A STUDY OF W BAND SUBHARMONICALLY PUMPED MIXER

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Abstract

A W band subharmonically pumped mixer with packaged Schottky diodes has been developed. The double sideband conversion loss of the mixer at $2f_{lo}$= 94GHz is 6.35dB. A new method for measuring the embedding network parameters of subharmonically pumped mixer was developed and the measurement has been carried out directly at $2f_{lo}$ and $2f_{lo}\pm f_{if}$. A special program for analysis of subharmonically pumped mixer has been developed and computed results are given in comparison with measured results.

1. Introduction

The key problem of accurate analysis and design of mixer is to determine the parameters of embedding network. Since this network usually consists of complex circuits, so it is difficult to determine its parameters through theoretical analysis. It has been proved that measurement is an applicable method. However, because of difficulties of measurement at millimeter waveband, most of measurements were made only with low frequency scaling model and only for single diode mixer(1)(2).

We have developed a W band subharmonically pumped mixer with packaged Schottky diodes. Performances of mixer including conversion loss, noise ratio and input VSWR have been measured. A new method for measuring embedding network parameters of mixer has been developed and the measurement has been carried out directly at $2f_{lo}\pm f_{if}$ and $2f_{lo}$. From these parameters, the performance of mixer has been computed with an analysis program of subharmonically pumped mixer. Comparison between computed results and measured results shows good agreement.

2. Design and performance of mixer

Fig.1 shows the circuits of W band subharmonically pumped mixer. The parameters of diode are shown in table 1. The operating frequencies and measured performances of mixer are shown in table 2. A Q band oscillator is used as LO source and a W band noise generator filled with argon is used for measurement of conversion loss and noise figure.

Table 1. Parameters of diodes.

Diode para.	R_s (Ω)	L_s (nH)	C_p (pF)	C_j (pF)	V_B (V)	ϕ (V)	I_s (A)
	5.0	0.1	0.2–0.3	0.04	7–8	0.75	5×10^{-9}

Table 2. Operating frequencies and performances of mixer.

Mixer para.	f_{LO} (GHz)	f_{if} (GHz)	L_c (DSB) (dB)	t_m (×290K)	input VSWR	P_{LO} (mW)
	46.84	1.2	6.35	321.9	1.2	8–15

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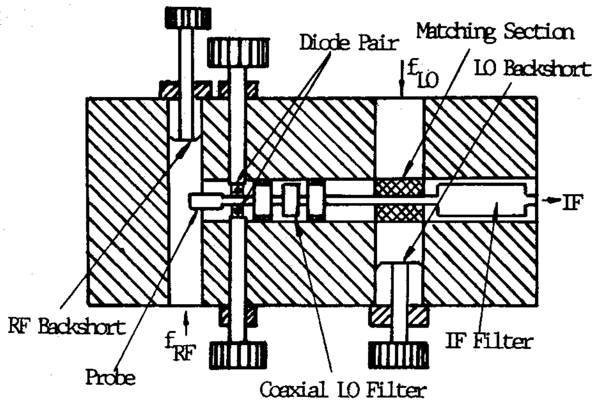
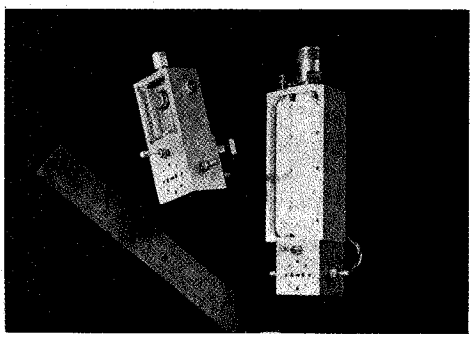


(a) Configuration



(b) Photograph

Fig.1 Circuit of W band subharmonically pumped mixer.

3. Measurement of mixer network parameters

Fig.2 shows the equivalent circuit of mixer. The embedding network includs total circuit except diodes. We put the packaged capacitance $2C_p$ of two

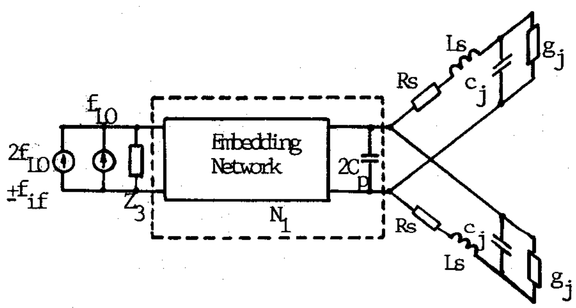


Fig.2 The equivalent circuit of subharmonically pumped mixer.

diodes with embedding network together and form a two-port network N_1. If the parameters of network N_1 have been known, the impedances seen from junction of diodes can be determined. Then the nonlinear and linear analysis of mixer are possible to be carried out. In order to measure the parameters of network N_1, we take one adequately biased diode put in place as a variable reactive load of two-port network N_1. At the same time another diode is put in place but its junction is broken. Therefore, the equivalent circuit for measurement is shown as Fig. 3.

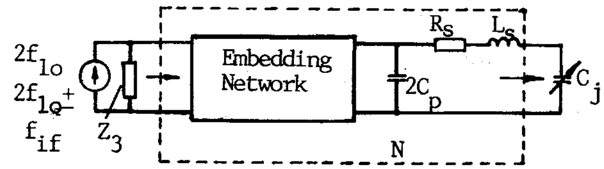


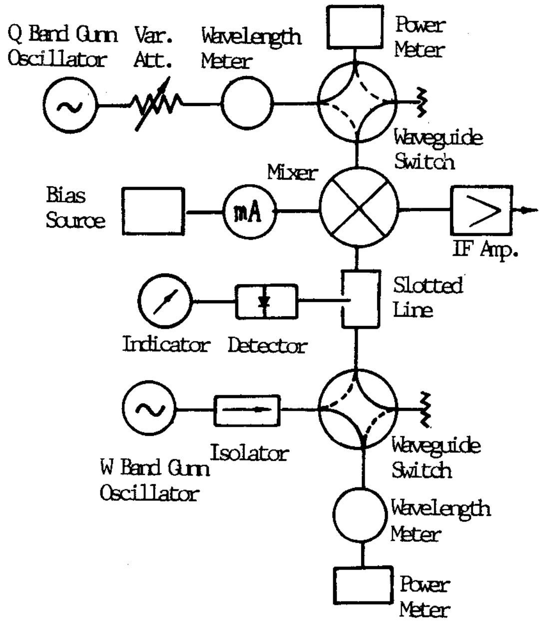
Fig.3 The equivalent circuit for measurement.

The biasing voltage of diode is changed from -5V to 0.5V and divided into 13 intervals. Since the current through the diode is very small when the voltage is less then 0.5V, so the junction conductance can be neglected. The relationship between input reflection coefficients Γ_{in} and load reflection coefficients Γ_c of N is given by

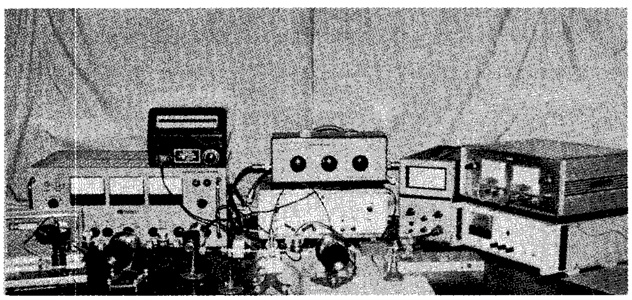
$$\Gamma_{in} = S_{11} + \frac{S_{12}^2 \Gamma_c}{1-S_{22}\Gamma_c}$$

Obviously, with variable Γ_c, the orbit of measured Γ_{in} is a circle. Fig.4 shows the block diagram and photograph. Fig.5 shows the measured three Γ_{in} circles corresponding to frequencies $2f_{lo}$ and $2f_{lo}\pm f_{if}$. In accordance with linear fractional comformal transformation and the theorem of four point cross ratio[3], a graphic method[4] was used to determine three important points (shown in Fig.6):

(a) O$'_1$ the partial centre of Γ_{in} circle and



(a) Block diagram



(b) Photograph

Fig.4 The test system of embedding network impedance.

the mapping of the centre 0 of Γ_c circle.

(b) T, the symmetric point of 0´in relation to Γ_{in} circle.

(c) C, the mapping of centre C´of Γ_{in} circle.

The scattering parameters of network N can be determined from locations of points 0´, C, and T. That is

$$S_{11}=\overline{OO'}$$

$$S_{22}^{*} = \overline{OC}$$

$$S_{11}-\frac{S_{12}^{2}}{S_{22}} = \overline{OT} .$$

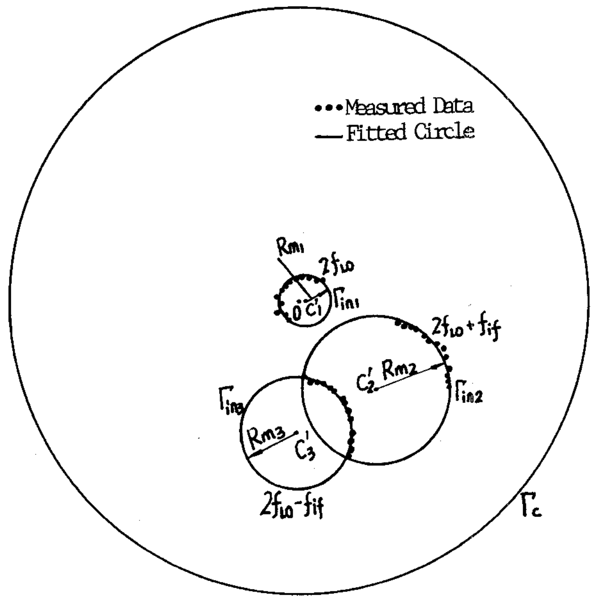


Fig.5 The measured Γ_{in} circles at three frequencies.

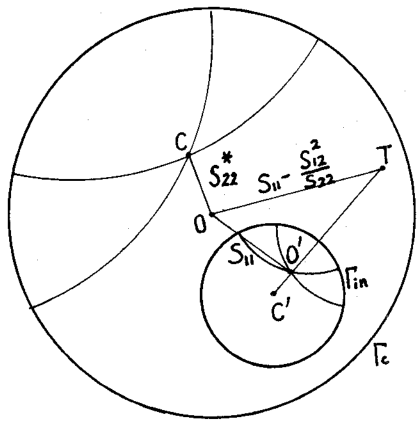


Fig.6 The relations between locations of points 0´, C and T and scattering parameters.

The radius of Γ_{in} circles can be calculated from scattering parameters

$$R = \frac{|S_{12}|^2}{1-|S_{22}|^2} .$$

The measured scattering parameters of network N and radius of circles obtaind from measurement (R_m) and calculation (R_c) are listed in table 3.

Since R_s and L_s have been given, so the parameters of network N_1 can be determined. This method of measurement also can be used to measure embedding network parameters at other LO harmonics and side-band frequencies.

Table 3. Measured parameters.

Fre. \ Para.	$2f_{LO}$	$2f_{LO}+f_{if}$	$2f_{LO}-f_{if}$
S_{11}	$0.023\angle{-90.5}$	$0.328\angle{-35.0}$	$0.359\angle{-95.5}$
S_{12}	$0.254\angle{61.04}$	$0.459\angle{-46.3}$	$0.412\angle{-40.3}$
S_{22}	$0.534\angle{51.0}$	$0.415\angle{5.0}$	$0.345\angle{4.2}$
R_m	0.087	0.262	0.200
R_c	0.090	0.254	0.192

4. Computed results

A special program has been developed for nonlinear and linear analysis of subharmonically pumped mixer. The nonlinear analysis is based on multi-reflection technique(5). The equivalent circuit for mixer analysis is shown in Fig.7 where the impedance parameters Z_4,Z_5 and Z_6 are determined from scattering parameters we have measured at $2f_{LO}$ and $2f_{LO}\pm f_{if}$ and Z_3 is the source impedance. The embedding impedance at other LO harmonics and sideband frequencies are given. They are listed in table 4. The computed results with analysis program are listed in table 5 and compared with measured results.

Table 4. Embedding impedances.

Fre. \ Imp.	f_{if},f_{lo} $f_{LO}\pm f_{if}$	$2f_{LO}-f_{if}$	$2f_{LO}$	$2f_{LO}+f_{if}$	above $2f_{LO}+f_{if}$
Z_6 (Ω)	50.0	$80.1\angle{69.7}$	$195.3\angle{-88.2}$	$168.0\angle{76.7}$	0.0
Z_5 (Ω)	50.0	$169.2\angle{-69.9}$	$267.8\angle{-79.7}$	$157.4\angle{78.1}$	0.0
Z_4 (Ω)	50.0	$227.3\angle{11.3}$	$154.2\angle{36.2}$	$349.6\angle{-27.0}$	0.0

Table 5. Computed and measured results.

Conversion loss (DSB)	measured	6.35(dB)
	computed	7.24(dB)
LO power	measured	13.5(mW)
	computed	22.8(mW)

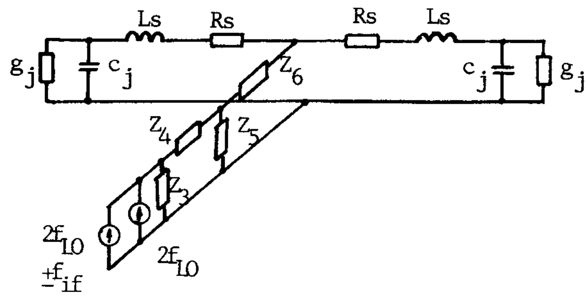


Fig.7 The equivalent circuit for analysis of subharmonically pumped mixer.

Conclusions

1. A W band subharmonically pumped mixer has been developed with packaged Schottky diodes. The features of this mixer are reliable and easy to change diodes.

2. A new method for measuring the parameters of the subharmonically pumped mixer embedding network has been developed and carried out at W band.

3. A special program for analysis of subharmonically pumped mixer has been developed and used for computation of mixer performances from measured network parameters.

Acknowledgement

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