MICROSTRIP MIXER DESIGN WITH IMAGE CANCELLATION AND LOW CONVERSION LOSS

Christian Ansorge

Technische Universität Hamburg-Harburg, Arbeitsbereich Hochfrequenz-technik, Postfach 90 14 03, D-2100 Hamburg 90, West-Germany

SUMMARY

A new layout of a microstrip mixer circuit for low intermediate frequencies will be described which uses a dielectric resonator in a simple configuration. It shows low conversion loss (3.2 dB at 7 GHz) due to image cancellation and a low noise figure.

INTRODUCTION

In downconverter mixers, unwanted frequency components should be prevented from taking part in the mixing process in order to obtain both low conversion loss and a low noise figure. Then these components must be terminated reactively. This imposes problems at the image frequency in particular for low IF. Image suppression in balanced mixers can be achieved either way: by using filters near each diode and at the signal input port, or by implementing a highly balanced circuit with two mixers and three hybrids. Low IF imposes, however, severe problems in both cases: Either the filter or the hybrid expense will be high. These difficulties can be overcome by the circuit proposed here which uses a dielectric resonator as a versatile filtering instrument.

MIXER DESIGN

On principle signals at $(\pm n\omega_s \pm m\omega_p)$, with n and m integers are generator in the mixing process between LO frequency ω_p and RF ω_s. The desired output at $(\omega_s - \omega_p)$ or at $(\omega_p - \omega_s)$, respectively, has to be matched while all other signals should be terminated reactively.

A balanced circuit configuration with a 3 dB-hybrid and open or shorted stubs for reactive terminations is most often used (Fig. 1). The selectivity of microstrip filters is, however, not sufficient at low IF so that different types of filters should be used. Dielectric resonators show a high Q-factor and seem to be well suited for such purpose. Aligning two resonators symmetrically (one at each diode) is, however, difficult. An alternate solution is illustrated by Fig. 2: A single dielectric resonator (DR) can be coupled to both microstrip lines. If it is tuned to the image frequency $(2\omega_p - \omega_s)$, and if it is mounted at a proper distance from the diodes, then the image is shorted so that no additional power loss can originate here. Any signal at the image is thus recovered. Hence the conversion loss will be low.

There is, however, another source delivering signals at the image frequency: the image frequency band at the mixer input port. It can be down-converted to IF thus raising output noise. These signals can be suppressed by optimizing their coupling to the DR. To this end, an additional line of a quarter of a wavelength must be inserted in one of the diode arms (Fig. 3). Thus any signal impinging at the signal port excites fields with equal polarity at the two ports of the DR so that the desired filtering effect is established. The response of the DR (Fig. 4) could give rise to losses at the LO frequency. This is, however, avoided by the inserted line length as well, because the DR is now decoupled from the LO port. (Both input ports of the DR are excited by LO signals being in anti-phase.) LO and RF ports of the hybrid may hence not be interchanged as it is possible in other mixer circuits.

MEASUREMENTS

Some mixer circuits were built with the following design figures:

ω_p = 7.125 GHz

ω_{IF} = 70 / 30 / 10 MHz

ω_s = lower sideband

P_{LO} = 10 mW

Fig. 5 shows the circuit layout. There are additional open stubs for diode matching and shorted stubs for establishing a reactive termination at the nearest critical frequency $(\omega_p + \omega_s)$. At the same time the stubs provide the DC return. The following material was used:

diodes: HP HSCH-5316 or
alpha DME 3051
(beam lead Schottky)

substrate:
RT/duroid 5880;
0.5 mm

0149-645X/85/0000-0687 $01.00 © 1985 IEEE 1985 IEEE MTT-S Digest

resonator:

trans tech D8515.312.124

With respect to the matching stubs the DR was mounted on a holder of material with low ε_r at a height of $\Delta h \approx 0.6$ mm. The distance to the diodes was $3/4\lambda$. For different IF, the resonant frequency was tuned by means of a large diameter tuning screw mounted on top of the completely metal housing.

Measuring the isolation between the connectors yielded

$$d(LO - IF) = 30 \text{ dB}$$

$$d(RF - IF) = 28 \text{ dB}$$

$$d(LO - RF) = 22 \text{ dB}$$

The conversion loss for two different coupling strengths of the DR (various Δh) and two IF is shown in Fig. 6. It can be seen, that a minimum conversion loss of 3.2 dB is achieved at 7.055 GHz. At the image frequency of 7.195 GHz, the conversion loss is about 35 dB. This means an image suppression of better than 30 dB. Fig. 7 shows the conversion loss of the mixer with the DR tuned to an IF of 10 MHz. Minimum conversion loss and image suppression are similar to what has been stated above.

The noise figure was measured with an automatic noise figure meter at an IF of 30 MHz. The measured value for the double sideband noise figure F_{DSB} is converted to the single sideband noise figure F_{SSB} by

$$F_{SSB} = 1 + \left(\frac{G_{Img}}{G_{RF}}\right) F_{DSB}$$

$$F_{DSB} \approx F_{SSB} \approx 4.2 \text{ dB}$$

with

G_{Img}: power gain at image frequency

G_{RF} : power gain at signal frequency.

CONCLUSIONS

A simple mixer circuit has been demonstrated being capable of low conversion loss and noise figure due to high image recovery. It is especially suited for low IF. The simple layout allows realizing the circuit at low cost so that it is suitable for mass production.

ACKNOWLEDGEMENT

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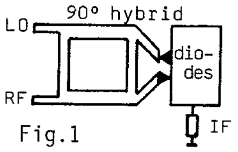

Fig.1

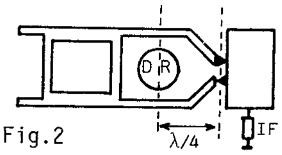

Fig.2

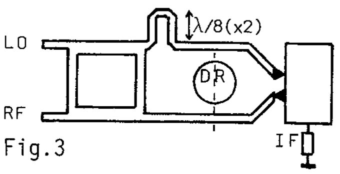

Fig.3

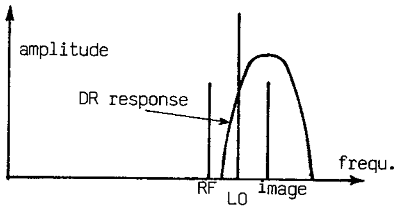

Fig.4: DR response

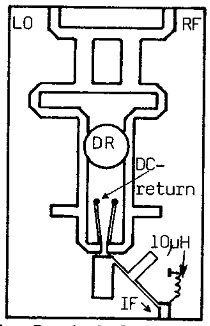

Fig.5: 1:1 layout

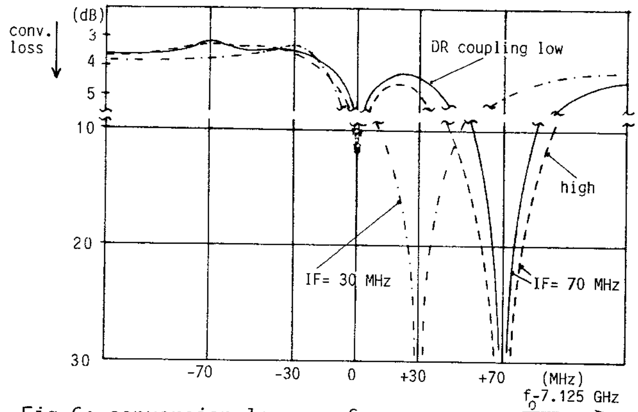

Fig.6: conversion loss vs frequency

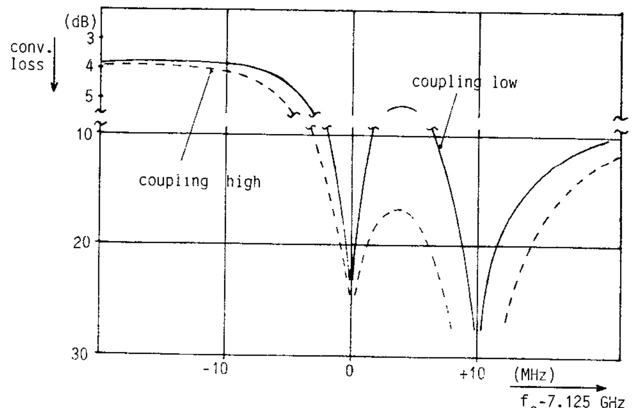

Fig.7: conv.loss vs frequency for 10 MHz IF