# WIDE-BAND MM-WAVE WAVEGUIDE MIXERS

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## 1. INTRODUCTION

In this paper some types of balanced, harmonic, subharmonic and sampling mixers are presented.

The balanced harmonic mixers on Schottky-barrier diodes (SBD), operating on the first LO harmonic with down conversion ($f_{IF} = |f_{RF} - f_{LO}|$) or up conversion ($f_{IF} = f_{RF} + f_{LO}$), harmonic mixers, operating on LO harmonics ($f_{IF} = f_{RF} - nf_{LO}$; $n$=2, 3, ...) and sampling mixers, operating on high numbers of LO harmonics ($n$ ~ 10...50) with preliminary formation of the pulse LO signal on the step recovery diode (SRD) have found wide application in a 18-180 GHz frequency range.

## 2. BALANCED MIXERS

Balanced mixers with complete frequency range 18-180 GHz, wide-band IF frequency 0-18 GHz and conversion on the first LO harmonic have the minimum conversion loss (6 – 13 dB) and noise factor in comparison with other types of mixers, that makes their usage preferable in radio measuring equipment with maximum sensitivity.

Structurally mixers are manufactured as hybrid MICs on dielectric substrates with various types of transmission lines (waveguide-slot line, microstrip, suspended microstrip, coplanar line) and their combinations and also serial mixing diode type 3A143, 3A147 etc.). RF input of the mixer is a rectangular waveguide; LO input - waveguide or coaxial, IF output - coaxial.

Typical characteristics of balanced mixer are presented in Fig. 1 *a, b*.

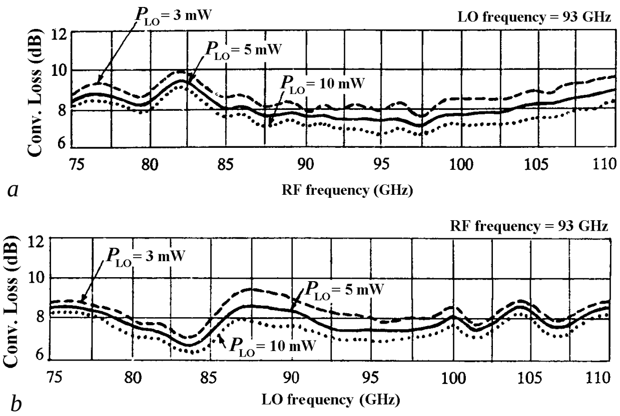


Fig. 1. Characteristics of the Balanced Mixer 75 – 110 GHz

One of the major tasks in balanced mixers design is the decrease of the required LO power to units of milliwatts, that would allow to use mm-wave semiconductor frequency multipliers as broadband local oscillators.

Perspective area of mm-wave balanced mixers application is the generation of spectral pure signals with multi-octave frequency coverage on in cm-wave range. Fig. 2 illustrates the opportunity of a creation of ultrabrodband pure signal source in a 0,1-20 GHz frequency range when mixing 53,1-73,1 GHz (P ~ 5 mW) and 53 GHz (P ~ 0,5 mW) signals and their difference frequency extraction are realized. The broadband mixers designed in IEM "KVARZ" are well suited to the solution of such tasks. Small conversion loss, wide-band at all inputs, uniformity and low LO power level is favorable to it.

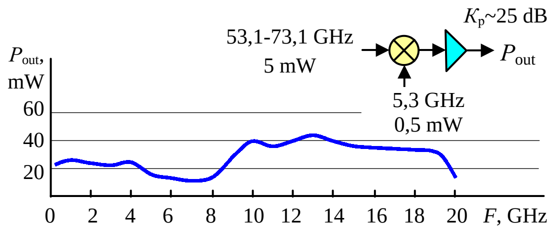


Fig. 2. Generation of ultra-broadband cm-wave signals

## 3. HARMONIC MIXERS

As opposed to balanced mixers with conversion on the first LO harmonic in harmonic mixers the useful signal selected at output has frequency $f_{IF} = |f_{RF} - nf_{LO}|$ at frequency downconversion of an information signal and $f_{IF} = f_{RF} + nf_{LO}$ at upconversion ($n$ ~ 2...10...). For odd LO harmonics a balanced circuit of the mixer is used, for even – a circuit with antiparallel diodes connection is used.

Series of models of harmonic mixers, covering frequency range 26,5-170 GHz by five models [1] is developed. Each of these models covers a complete frequency range of the waveguide without using tuning elements. The frequency conversion is carried out on 3 - 8 harmonics at re-tuning LO in 8 - 14 GHz frequency range. The use of more lowly LO harmonics in comparison with widely known series 11970 of harmonic mixers of "Hewlett Packard " has allowed to decrease conversion loss. In the designed mixers the relatively small frequency dependence on conversion loss is guaranteed at constant LO power. The mixers have a built-in diplexer for of LO and IF frequencies division. Main characteristics of harmonic mixers are listed in Table 1.

## 4. SUBHARMONIC MIXERS ON SMALL NUMBERS (n = 2, 3) LO HARMONICS

From the variety of harmonic mixers we can distinguish a group of mixers with conversion by 2-nd or 3-ed LO harmonics, named subharmonic mixers. It is preferable to use them at signal frequencies above 70 GHz, where harmonic mixers with conversion on high numbers of LO harmonics have large, frequently unacceptable, conversion loss, and for balanced mixers with conversion on the first LO harmonic local oscillators (especially frequency re-tuned) with a sufficient power level are unrealized.

Harmonic Mixers specifications Table 1

| Model | RF range (GHz), Wave-guide | LO range, GHz | Number of LO harmonic | IF range, MHz | Conv. Loss (Max), dB | Conv. loss flatness at $P_{LO}$ = const, dB |
|---|---|---|---|---|---|---|
| 7002 | 26,5-40 WR-28 | 8.83-13.33 | 3 | 10÷100 | 24 | ± 2.5 |
| 7003 | 33-50 WR-22 | 8.25-12.5 | 4 | 10÷100 | 26 | ± 2.5 |
| 7004 | 50-75 WR-15 | 8.33-12.5 | 6 | 10÷100 | 32 | ± 3.0 |
| 7005 | 75-110 WR-10 | 9.38-13.75 | 8 | 10÷100 | 36 | ± 3.5 |

For 78-118 GHz a subharmonic mixer with conversion by 2-nd LO harmonic is developed. LO frequency range 40-54 GHz, IF – 0.025-18 GHz. LO power 15-20 mW. Conversion loss ≤ 15 dB.

## 5. SAMPLING MIXERS (SAMPLING CONVERTERS)

Many types of sampling converters (1- and 2-channel) are designed for use with mm-wave radio measuring equipment. Five types of waveguide-mixers cover frequency range from 26 to 180 GHz. The mixer of coaxial type covers 0-40 GHz. 36 to 120 GHz mixer with a wide-band input waveguide of Π-form section is designed.

Sampling converters are used for downconverting signal frequency of mm-wave band. In design process of mm-wave sampling converters the sampling technique of frequency conversion and thin-film hybrid technology is used.

The input signal path is formed by a wide-band waveguide-microstrip transition made as a seven-step Chebyshev transformer from a rectangular waveguide section to the Π-form section, and also by 50 Ohm microstrip line, made for loss minimization on thin quartz substrate. Mixing node base is a monolithic diode pair with low parasitic, practically noninductively connected to the combination of slot and microstrip lines not coupled with each other.

Short gate pulses formed by a slot line cavity are applied to diodes through storage capacitors. The pulses periodically open the diodes for a short period of time with LO frequency. To cover the frequency range up to 180 GHz it is necessary to generate a gate pulse of not more than 3-5 ps duration with effective voltage amplitude at 0.3-0.5 V diode. For this reason a special small-size Si SRD, made by bipolar technology with extremely short transition time (less 20 ps), was constructed.

All this has allowed to have:

- comparatively low conversion loss (30-35 dB, up to 78 GHz and 50-55 dB, up to 180 GHz) for a large number of LO harmonic measurements (20 and more);
- high isolation of mixer LO and signal inputs (40-50 dB);
- low sensitivity of conversion loss to LO power level variation;
- low phase noise level.

Typical performances of sampling mixers in detail are presented in special issue [2].

Besides a new mixer model for frequency range from 120 to 180 GHz is designed. Mixing base is a waveguide section with a slot line cavity in a broad wall of waveguide and with a wedge along an opposite wall. The monolithic diode pair is connected to the combination of a slot and a wedge. This construction has a smaller conversion loss (about 50 dB), and it is possible to extend the frequency range above 180 GHz.

The above mentioned sampling converters are successfully used in frequency stabilization and synchronization systems, designed for mm-wave frequency synthesizers up to 180 GHz, and are used nowadays for development of sampling oscilloscopes, frequency counters, network analyzers, etc.

## 6. CONCLUSIONS

Presented mixers are elements defining frequency range, sensitivity and other characteristics of radioreceiving devices and radiomeasuring instrumentation. The mixers are used as input devices of spectrum analyzers, receivers, network analyzers, frequency counters.

For the last years the nomenclature of the designed mixers is increased, their frequency range is extended, the required LO power and the conversion loss is reduced.

## 7. REFERENCES

[1] Catalogue of Institute of Electronic Measurements “KVARZ”, 2002.

[2] С.В. Панков, Р.К. Стародубровский, А.М. Щитов. Волноводные смесители миллиметрового диапазона. - Радиоизмерения и электроника, 2001, вып. 9, с. 32-39.