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Ka-BAND MICROSTRIP INTEGRATED LOCAL-OSCILLATOR-MIXER ASSEMBLY USED IN PROJECTILE SENSORS*

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Abstract A compact Ka-band microstrip integrated local-oscillator-mixer assembly used in projectile sensors was introduced. The overall configuration of microstrip circuit of this assembly was given. The functions of each component were described. The environment and reliability tests performed on this assembly were explored in detail, which include vibration, shock and temperature. The Ka-band local-oscillator-mixer assembly exhibits a 3.4～4.2-dB double side band (DSB) noise figure over a 2-GHz RF bandwidth. LO-to-RF isolation is greater than 27dB over the range of operating frequencies. The frequency stability of local oscillator with dielectric resonator used is less than 60ppm/℃.

Key words local-oscillator-mixer assembly, DSB noise figure, frequency stability, dielectric resonator.

用于抛掷敏感器的Ka-波段微带集成本振-混频组件*

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摘要　介绍一种用于抛掷敏感器的结构紧凑的Ka-波段微带集成本振-混频组件，给出了该组件的微带电路结构，叙述了其中每一部件的功能，对该组件仔细做了环境和可靠性实验，其中包括震动，冲击和温度．在2GHz射频带宽内，该组件的双边带噪声系数是3.4～4.2dB，在其工作频带内本振到射频的隔离度大于27dB．由于使用了介质谐振器，本振的频率稳定度小于60ppm/℃．

关键词　本振混频组件，双边带噪声系数，频率稳定性，介质谐振器．

Introduction

As a very important RF subsystem used in projectile sensors, local-oscillator-mixer assembly must be small size, light weight, high performance to meet requirements of whole specifications, and withstand military-standard vibration, shock and temperature tests. To meet the above-mentioned requirements, a compact local-oscillator-mixer assembly with dielectric resonator used was developed in our Laboratory. Although many papers about mm-wave oscillators and mixers have been reported in past several years, it is inconvenient to combine them to construct mm-wave local-oscillator-mixer assembly and to meet the above requirements[1,2]. The cavity-stabilized mm-wave oscillator has high frequency stability, but its volume is not acceptable while used in this assembly. Although the integrated fin-line and microstrip mm-wave oscillator have suitable size, if any stabilized

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frequency approach has not been adopted, its frequency stability can not satisfy the requirement. With the emergence of dielectric resonators operating in Ka-band, despite of its Q-factor not very high as compared with the cavity, it becomes possible that a microstrip integrated mm-wave local-oscillator-mixer can be developed. After comprehensive considerations, a microstrip integrated local-oscillator-mixer assembly has been developed. The circuit supplies many adjustable portions to adjust the oscillator frequency and output power to ehnance the performance of mixer. The DSB noise figure of this assembly is 3.4~4.2dB over an instantaneous IF bandwidth of 100~200MHz. The production generally withstands military-standard vibration, shock and temperature tests. The production of this assembly is not a multi-step labor-intensive process with a high success rate.

1 Configuration of the Assembly

A planar integrated mm-wave local-oscillator-mixer assembly which operates in Ka-band is shown in Fig. 1. The configuration consists of two connecting constituents, of which each one can be used as an independent mm-wave component while it is separated to two parts. The right part is a microstrip mixer with rat-race configuration, and the left is a microstrip oscillator with two mechanisms used to adjust frequency and output power.

The mixer consists of a ring-type power splitter, one dc block, two mixer diodes, two RF chokes, and a low-pass filter. The Ka-band mixer was designed to operate at 35.2GHz and was fabricated on 10-mill Duriod substrate[3]. The LO input

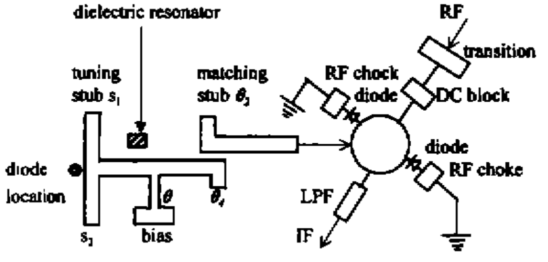

Fig. 1 LO-mixer assembly layout showing microstrip oscillator and Rat-Race mixer
图1 本振-混频组件电路示意图

is split equally into two mixer diodes. The RF input is also split equally, but 180 degrees out of phase at the mixer diode location. The diodes were mounted in reversed positions. The LO and RF are mixed in these diodes which generate signals that are then combined through the ring and taken out through a lowpass filter. The RF choke provides the tuning mechanism and prevents the RF signal from feeding into ground. The dimension of the ring is critical. It is 1.5-wavelength in circumference with four arms separated by 60 degrees of angular rotation. Two input and output arms are spaced from one another. The design of the ring requires that the impedance of the main ring be equal to $\sqrt{2}$ times the characteristic impedance of each arm. For a 50Ω system, this main impedance is equal to 70.7Ω. Operating around central frequency (less than 10% bandwidth), the LO/RF isolation is over 20dB.

To obtain high performance of mixer, the local oscillator must operate around 35.2GHz, and supply proper LO power to mixer. In this configuration of assembly, LO pumping power requirement is about 8 to 10 dBm. So, the local oscillator of assembly connecting to the rat-race mixer should supply feasible frequency and adjustable output power.

A microstrip millimeter generator is schematically represented in Fig. 1 (left part). In order to effectivly use the microstrip approach, it is desirable to separate the two processes of tuning (adjustment of signal frequency) and matching (adjustment of the impedance presented by the circuit to the microwave diode)[4,5]. A tuning network, generally consisting of two open-ended stubs, provides a reactive impedance component across the diode terminals. Adjustment of this reactive component, by trimming off the stub lengths, serves to adjust the frequency of the signal; the oscillator occurs at the frequency at which the susceptances of the diode and of the outside circuit just cancel each other out. The remaining real part of the generator impedance is in general different from the line impedance, most often chosen at the con-

Table 1 Measurement results of DSB noise figure and oscillation frequency

表 1　双边带噪声系数和振荡频率测试结果

IF frequency (MHz)	DSB noise figure	IF frequency (MHz)	DSB noise figure	IF frequency (MHz)	DSB noise figure
100	3.7	100	3.6	100	3.4
150	3.8	150	3.9	150	3.6
200	4.1	200	4.2	200	4.2
$T=25$ C $f_L=35.21$GHz		$T=100$ C $f_L=35.05$GHz		$T=60$ C $f_L=35.39$GHz	

ventional value of 50Ω, so that some kind of transformer is necessary to connect the generator to the load. The reactively terminated coupled line here behaves as an adjustable transformer. The impedance ratio of such a transformer can be adjusted by modifying the electrical length of matching stub.

The Gunn diode is located at the T-junction, fitting in hole drilled through the substrate, between the upper conductor and the ground plane. The length of the two open-ended stubs s_1 and s_2 was adjusted for oscillation at the design frequency of 35.2GHz. A half-wavelength section of line between the diode and the coupler input severs to avoid interference between the stubs. The length of stub θ_2 is adjusted for appropriate output power (8-10dBm).

The length of stub θ_2 is adjusted for appropriate output power (8－10dBm) (Fig. 2); the adjustment must be made carefully as the curve presents a rather sharp maximum. The signal produced was observed on a spectrum analyzer. The line is quite sharp and there are no spurious oscillations.

Further refinements considered are the addition of varactor diodes for fine tuning and matching. Variable capacitors with adequate biasing circuits placed at the ends of stubs S_1 and S_2 can be used to adjust the frequency of operation or to FM modulate the signal. At the end of stub θ_2, a variable capacitor can be used to adjust the power level (ALC) and for amplitude modulation of the signal.

The dielectric resonator operating in mm-wave range locating beside microstrip line was employed as stabilized frequency element[6]. For ease of fabrication, the dielectric resonator was used in a rectangular shape. The principal resonant mode is the $TE_{11\delta}$, and to minimize the interference of spurious modes, the aspect ratio of the resonator, H/A, is from 0.3 to 0.5, where A, B ($A=B$) and H are the resonator length, width and height, respectively. The resonator was positioned directly on the substrated $\lambda_g/4$ from the Gunn diode. The desirable frequency and optimum performance can be obtained with metal tuning screw, and by changing the depth of cover of metal enclosure.

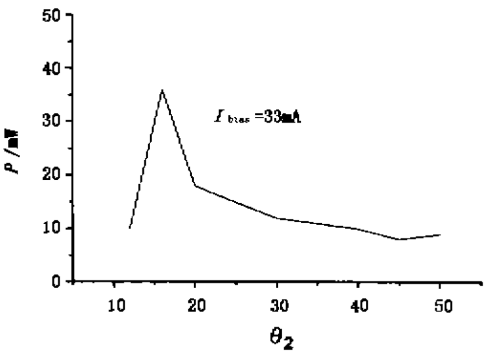

Fig. 2 Output power as a function of electrical length of stub θ_2, at 35.2GHz, for $\theta_4=15°$, $\theta=120°$, $Z_{oe}=67\Omega$, $Z_{oo}=33\Omega$

图 2　35.2GHz频率下输出功率和枝节θ_2的电长度的关系 ($\theta_4=15°$, $\theta=120°$, $Z_{oe}=67\Omega$, $Z_{oo}=33\Omega$)

2　Performance of the Assembly

After completing fabrication of this assembly, various intensive measurements have been done in our laboratory. DSB noise figure measurements were made using Noise Figure Meter (HP8970B), and the results are shown in Table 1. The local oscillator frequency measurements were made using Spectrum Analyzer and the results are also shown in Table 1.

Table 2 Summary of environmental and reliability tests performaed on the assembly
表 2 组件的环境和可靠性测试

TEST	STANDARD
VIBRATION	FIGURE2 CURVE 10 3AXES 2HOURS
SHOCK	3AXES 8000g
TEMPERATURE	CYCLING FROM-60℃ TO 100℃ TEN TIMES

3 Environmental Tests

Table 2 summarizes a series of environmental and reliability tests which were performed on this assembly. The environmental and reliability tests include vibration, shock and temperature[7]. The assembly exhibited no measurable degradation.

4 Summary and Conclusion

A 35. 2 GHz local-oscillator-mixer assembly using beam-lead mixer diodes, microstrip and dielectric resonator technology has been developed for projectile sensor applications, exhibiting DSB mixer noise figure of 3. 6～4. 2dB and local oscillator frequency stability of 60ppm/℃. It demonstrates a high degree of electric and mechanical ruggedness. Finaaly it is designed for mass production, avoiding the costly and labor intensive procedures.

REFERENCES

[1]Cohen L D. Advance in printed mm-wave oscillator circuits, *IEEE MTT-S International Microwave Symposium Digest*, 1980, 264—266

[2]Peter Tor Parrish, Apostle G Cardiasmenos, Israel Galin. 94GHz beam-lead balanced mixer, *IEEE Trans.*, 1981, MTT-**29**(11): 1150—1157

[3]Chang Kai, Sun Cheng. Recent advances in millimeter-wave integrated circuits, *SPIE*, 1985, **544**: 103—107

[4]Rutledge D B, Schwarz S E. Design microstrip oscillators with coupled line matching, *Microwave Journal*, 1980, **23**(6): 65—67

[5]Mazumder S R, Gendiol F E. Coupled line circuit with adjustable input conductance, *Electronic Letters*, 1979, **15**(3): 91—93

[6]Weinreb S, Kerr A T. Cryogenic cooling of mixers for millimeter and centimeters wavelengths, *IEEE J. Solid-State Circuits*, 1973, **8**: 58—63

[7]Plourde James, Ren Chung-Li. Application of dielectric resonators in microwave components, *IEEE Trans.*, 1981, MTT-**29**(8): 754—770