U-Band Shield Suspended-Stripline (SSL) Gunn DRO and VCO

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Abstract:

The first mm-wave IC Dielectric Resonator Oscillator (DRO) in SSL has been developed. The DRO in a unique configuration with output power of more than 17dBm and the mechanical tuning range of 1.5GHz at 54GHz has been obtained.

A Varactor-Controled Oscillator (VCO) with out-put power over 15dBm across the 1000 MHz electronic tuning bandwidth at 53 GHz also has been developed.

Introduction

U-band (40 - 60GHz) is a dominant mm-wave frequency range for secure military communications and meteorology. The development of high performance mm-wave IC RF front end is being spurred by the incresing interest in the U-band. Even though the mm-wave Solid-State Oscillators are the essential circuit components, but the mm-wave Solid-State Oscillator with acceptable system performance constructed in integrated technology is still not available yet. Therefore, much attention has been paid to mm-wave IC solid-state sources with low phase noise and high frequency stability.

A wide variety of oscillators has been constructed in Microstrip[1-3], Finline[4], Dielectric waveguide [5], Lumped elements [6] and SSL[7]. It is obvious that DRO's are an uncomplicated approach to the necessery sources for use in communications and meteorology systems. So far, howevere, mm-wave IC DRO reported in the literature have been fabricated using microstrip[1-3].

This paper reports the first mm-wave IC DRO in SSL. This Gunn DRO offers several advantages over a unit in microstrip. A 3SL VCO in the same band was also presented.

SSL DRO

The DRO is shown in Fig.1. The Diclectric Resonator (DR), which used in the DRO, was fabricated by the Nanjing Solied-State Devices Research Institute (NSR).The parameters of DRs are listed in table 1. The WT57 Gunn diode, using WD-085 microwave package, is produced by NSR. The circuit broad-substrate,similar to the RT/DUROID 5880, is a non-woren glass microfiber-reinforced PTFE (developed by Shanghai Plastics Research Institute).

SSL is well adapted to short mm-wave. There are no drawbacks such as difficult grounding of a soft substrate, narrow solt fabrication or thin lines for bias or dc blocke. Several requirements, for example, making substrate holes, welding metal leads to the diode's cap or bonding wires in microstrip, were omited by simple and reliable surface connections between the diode and the metal strip of the SSL. These measures guaranttee uniform devices and facilitates device replacement. Take into account of the expensive price and poor uniformity of the devices, which be used in the mm-wave freguency range, the mentioned adopted measures are rather valuable.

Fig. 2 show a photograph of the SSL DRO. The corresponding equivalent circuit is represented in Fig. 3. This is a band-reject type, DR stabilized Gunn oscillator with single tuned behaviour. The DR with dummy load was coupled to the SSL behind the Gunn diode to form the band rejection filter. The output power was fed into a WR19 waviguide through a probe (omit DC block) from the other side of the SSL. The DC bias network for the Gunn diode was placed on the lower side of the substrate. The DR and related SSL resonation system, coupled by a broadside-coupler with Gunn diode, were arranged on the upper side of the substrate. Because the DR is 'Suspended' and is away from 'Ground', the usual degradation of Q value was reduced. The distance between the diode and DR was not limited by their transverse size due to their separation by the substrate. Let h_2 of channel equal to the height of Gunn diode and a quarter - wavelength matching transformer was used for impedance matching to set the impedance seen by the diode.

Fig. 4 illustrates the bias tuning characteristics of the DRO. Curve (A) represents stabilized performance. Curve (B) shows the behaviour without DR which was replaced by a SSL short and the oscillation frequency was adjusted to the same value as frequency with DR. Compraring A to B, a stabilization factor of 10 was achieved. Fig. 5 shows the behaviour of DRO with respect to tuning post insertion depth. Outpur power of over 17dBm with mechanical funing range of 1.5GHz at 54 GHz has been measured. The oscillating frequency increases linearly with insertion depth 's' of the tuned post. Noth that df/ds>o, as opposed to df/ds<0 in capacitive-load tuning. The tuning slope is in agreement with calculated results, illustrating that the DR functioned as intended. Such high and positive slope as 9GHz/mm allows the selection of DR materials with higher Q, although this type of Z_rO_2-S_nO_2-T_iO_2 has τ_f<o, to reduce FM noise of the oscillator while the τ_f of the oscillator can approach 'zero' by means of double-metal compensation.

SSL VCO

A SSL VCO, with more extensive value for mm-wave application, was also developed in U-band. The layout of the VCO are shown in Fig. 6. Major differences are as follows (1) Tchebycheff low-pass filters of 7 sections high-low impendance, fabricated at the proper positions on the both side of substrate, replace the DR system and Gunn diode bias network. (2) A varactor (NSR type WB62 Hyperabrupt junction GaAs Varactor), action as a electronic tuning element, was mounted against the Gunn diode in h_1 channel.

Fig. 7 provides a photograph of the SSL VCO. Its equivalent circuit is described in Fig. 8. By appropriate design of Z_D, Θ_D, Z_r, Θ_r and coupling K, a varactor-controled oscillator (VCO) delivering power of over 15dBm across 1000MHz electronic tuned bandwidth at 53GHz (shown in Fig. 9) was obtained. In this investigation, complete integration has been realized and the tuning bandwidth has been boosted by comparison with reference <7> where a sliding short was employed in the SSL channel.

Conclusion

A U-band DRO and VCO, with excellent performance, constructed in SSL, have been demonstrated. The author is confident that the configuration can be made to operate at shorter milimeter wavelengths and can find application in mm-wave IC negative resistance oscillotors.

Acknowledgements

The author wish to thand Mr. lin Jin-ting, Chief engineer of NSR, for sincere encouragement. The author also gratefully acknowledges the following: Mr. Wang Fu-ding of Shanghai Plastics Research Institute for providing dielectric broad, Mr. Tang Bieng-q qian, Mr. Hu Rong-zhung, Mr. Yie Mieng and Mr. Xia Yong-xiang of NSR, respectively, for providing DR, Varactor, IC fabrication and assistant work.

This work has been supported by science Foundation of Microelectronic Bureau of Electronic Industry Ministry.

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Table 1. Parameters of Dielectric Resonators

Materials	$Z_rO_2 - S_nO_2 - TiO_2$	$Ba(Z_{n.33}N_{b.67})O_3 - B_a(Z_{n.33}T_{a.67})O_3$
Relective Dielectric Constant (ϵ_r)	37.5	29.7
Mode (Cylindrical)	TE_{01}	TE_{01}
Unloaded Q_0 (measured at 10GHz)	4300	9800
Loaded Q_L (measured at 45GHz)	212	396
Dimension (Ø(mm) x H(mm))	1.0 x 0.41	1.2 x 0.46

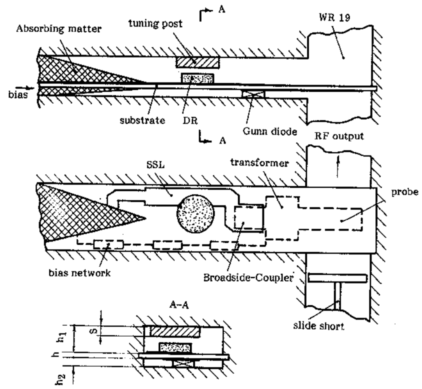

Fig 1 Schematic of the SSL DRO (low surface dashed lines)

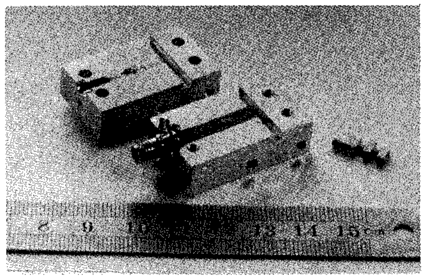

Fig 2 U-band SSL DRO

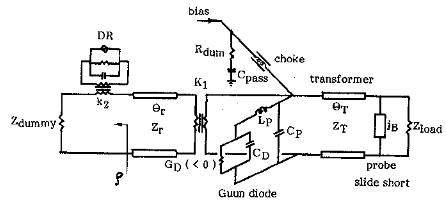

Fig 3 Equivalent circuit of the SSL DRO

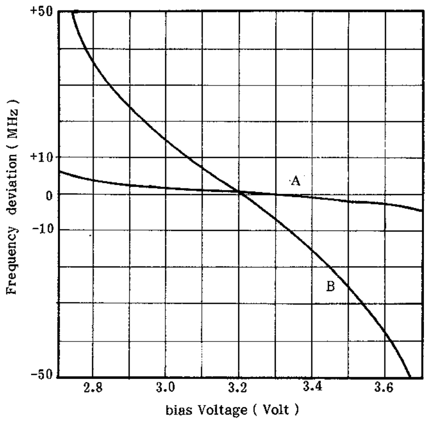

Fig 4 Frequency-Bias Characteristics of the SSL DRO

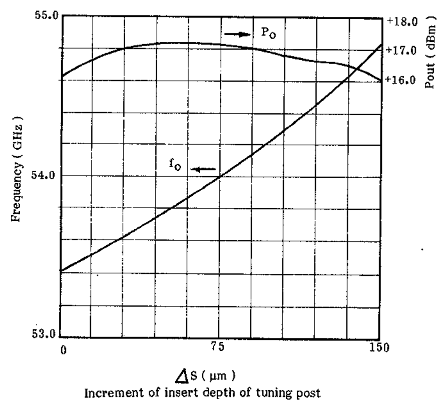

Fig 5 SSL DRO Performance

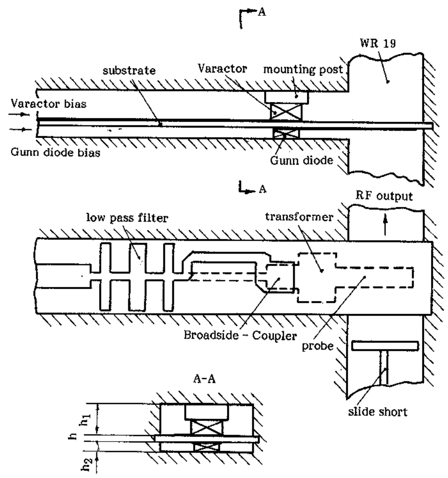

Fig 6 Construction of the SSL VCO (lower surface dashed lines)

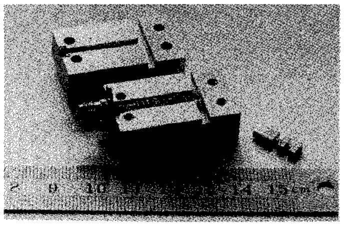

Fig 7 U - band SSL VCO

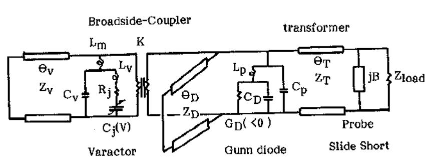

Fig 8 Equivalent circuit of the SSL VCO

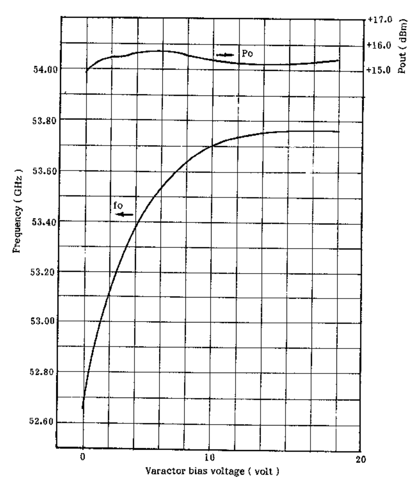

Fig 9 SSL VCO Performance