THEORETICAL STUDY OF HARMONIC INJECTION LOCKING OF MILLIMETER WAVE HARMONIC GUNN OSCILLATORS

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Received October 7, 1994

ABSTRACT

Harmonic injection locking behavior of millimeter wave second harmonic Gunn oscillators is studied based on an equivalent circuit model. A large signal model of Gunn device in harmonic mode operation is employed. Injection locking curves of voltage amplitude and phase difference between injected current and harmonic voltage are calculated by means of describing function technique. Stability of the locked harmonic oscillators is also investigated. It is revealed that the harmonic locking bandwidth is much smaller than that of fundamental wave oscillators and is closely related to the susceptance slope parameter of fundamental wave circuit. It is also found that the stable region is smaller than that of fundamental wave oscillators. Some conclusions have been made for the application of harmonic injection locking technique.

1. INTRODUCTION

Although millimeter wave second harmonic oscillators of solid-state device have been applied in many millimeter wave systems, the study of their phase locking behavior is still at its beginning stage.

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The experimental and theoretical works on this subject reported in last few years\textsuperscript{[1]}\textsuperscript{[3]} concerned about second harmonic oscillators injection locked by fundamental waves. These results contribute a lot to the development of phase locking technique of millimeter wave harmonic oscillators. However, the study of harmonic injection locking of harmonic oscillators has hardly been reported till now. This subject is deserved to be investigated since its potential application scope is also wide in harmonic wave synchronization and amplification. The purpose of this paper is to study the harmonic wave injection locking behavior of millimeter wave second harmonic Gunn oscillators. By means of describing function technique, harmonic injection locking curves of voltage amplitude and phase difference between injected current and harmonic voltage are calculated based on a large signal model of the Gunn device. Maximum locking bandwidths are obtained. Stability criteria of the locked harmonic oscillators is derived.

\section{Circuit Equations}

Fig. 1 shows an equivalent circuit of a second harmonic Gunn diode oscillator, where $G_2$ represents harmonic load conductance, $I_{i2}$ is an injected current at second harmonic frequency, $L_N$ stands for a frequency multiplexing network, $D$ represents the Gunn device.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{fig1.png}
\caption{Equivalent circuit of a second harmonic oscillator}
\end{figure}

The large signal model of the Gunn device is described by the following van--der--Pol $I$--$V$ characteristic with a quadratic term included

$$i_d = b_1 v_d + b_2 v_d^2 + b_3 v_d^3$$ \hspace{1cm} (1)

It should be mentioned that, when the oscillator operates in a harmonic mode, the expansion coefficients $b_j (j = 1, 2, 3)$ in the $I$--$V$