# FEED BACK STABILIZATION AND NOISE REDUCTION IN SOLID STATE MULTIPLIER CHAINS

C. Louis Cuccia
Alex Savarin

PHILCO-FORD CORPORATION
Palo Alto, California

Many papers have been written concerning the theory, design, techniques, and measurements relating to power sources consisting of chains of transistor oscillators and amplifiers and varactor multipliers. In general, these papers have emphasized circuit design and in particular, have made an enormous point of designing for optimum power conversion efficiency. However, attractive high efficiency may be from the device standpoint, power stability and low noise output are far more important parameters from the system standpoint in which the chain is used, to assure continuous spurious and noise free circuit operation, even at the sacrifice of output power.

The practical considerations of the noise and spurious signal content of the output power and the overall problem of system stability have in general, received very little attention other than a small number of published papers directed for example, toward considerations of instabilities by C.B. Leeson[1] and M.E. Hines[2], white noise in the vicinity of the output carrier as a function of temperature by C.L. Cuccia, J. Napoleon and D. Nelson[3], the effect of FM noise originating in the driving oscillator by M.E. Hines[4], and phase stability as a function of temperature by R.A. McConnell[5]. This paper outlines a new and highly effective approach to multiplier stabilization which not only results in significant improvement in output spectrum purity and reduction in adjacent - carrier noise, but also actually greatly reduces the requirements for many of the stabilization techniques described above.

In the operation of frequency multiplier chains starting with crystal controlled oscillator power below 100 MHz and multiplying with total multiplication values in excess of two hundred, to Ku, K, and Ka band, there are many approaches which can be taken to minimize chain instability and reduce noise in the vicinity of the output signal. These approaches which are described in the above references include:

(1) minimizing X-tal oscillator FM thereby minimizing PM to AM conversion,

(2) minimizing parametric subharmonic oscillations, thermal relaxation oscillations and high order resonance oscillations, by careful filtering of desired harmonics, by proper varactor biasing, and by the elimination of passband discontinuities,

(3) improved impedance matching which provides optimal interstage matching and which provides intra-stage matching to each varactor at each desired harmonic frequency, and which reflects or suppresses unwanted harmonics; not developing idler current paths which lower conversion efficiency and produce spurious response,

(4) the use of adequate bandwidths for all matching networks such that small changes in varactor impedance and bias do not produce detuning effects,

(5) leveling of the power at the output frequency of a multiplier chain by detecting this power and comparing the detected power level and a reference voltage in a servo-controlled attenuator at the output frequency to render the output power level constant against power level changes produced within the chain.

All of these approaches, and in particular, optimized impedance matching and the control of undesired harmonics, are most effective to providing stable relatively - clean output spectrum. Power leveling assures a measure of output power level stability but contributes to neither system stability or spectrum purity.

This paper describes a new approach multiplier stabilization, wherein the power at the output frequency is detected and the detected output signal is employed to drive an automatic feedback circuit which controls a level determining circuit at a lower frequency stage, operating in an automatic gain control (AGC) mode similar to that used to control the gain of receivers.[6]

The automatic feedback circuit uses a linear servo loop consisting of high gain wide-band feedback amplifier which is controlled by a detected portion of the output power at the output frequency using a detector with video bandwidth. The feedback amplifier compares the amplified detected signal with a stable reference signal, and controls a PIN diode attenuator which is in a series mode between two lower frequency stages in the multiplier chain. The PIN diode attenuator has the features of operating over a very wide near-octave bandwidth as an absorption type device and providing constant imput and output resistive impedances at all useful attenuation levels.

By using an inverse feedback servo loop designed with a transient response and a bandwidth related to the effective noise bandwidth of the output signal and the frequencies of control and detection, the control circuit becomes more than a mere power leveler, providing both active stabilization of the power output of the system and the reduction in spurious and white noise in the vicinity of the output signal.

In general, the stabilization effect is multifold in influence. The multiplier stages controlled by the feedback loop present a virtually impedance-invarient wideband load to the uncontrolled driving stages. This impedance invarient load provides the function of not only absorbing interstage harmonics at that point, but also serves to readjust and compensate for power amplitude changes due to both phase changes in harmonic current and frequency variations in power in the lower frequency transistor amplifier and frequency multiplier stages, and to significantly suppress higher order mode instabilities. The PIN diode attenuator which couples the controlled stages to the uncontrolled stages acts to pass only the required power which maintains output power level constant, regardless of the point of amplitude change - whether in the loop controlled stage or in the lower frequency stages.

In the servo-loop controlled stages, any input power fluctuations which are not smoothed by the attenuator are further amplitude stabilized, and again, a compensation amplitude-change due to phase change takes place, particularly where the output load is a phase sensitive device such as a parametric amplifier. The idler currents of the final multiplier stage, when considered in the classical Kauffman-Douthett mode, are provided with apparent impedance stability and introduce an additional measure of power stability.

The use of high-selectivity interdigital filters[8] with increased single stage bandwidth at the interface of the uncontrolled driving stages and loop controlled stages is a further noise control parameter which contributes to this system. The interdigital filters, as load impedances to the varactors, have the feature of introducing broadband flat-top pass-bands for the active harmonics with minimum AM to PM conversion. Also, by designing the interdigital filters with high selectivity and with high order filter modes shifted to frequencies well above the second and third harmonics of the principal frequencies, high frequency current modes from the varactor can be suppressed such that they do not pass into the feed-back stabilized circuits and provide erroneous output signals for the loop to respond to.

Noise reduction is another direct advantage of this feedback stabilization, due to both improved varactor impedance matching, and to the minimizing of mean square error in final stage conversion efficiency where the signal level, noise level, and reaction time performance are specified in a manner similar to classical AGC closed-loop theory. By designing the automatic feedback loop, and its detector and PIN-diode attenuator circuits with a bandwidth of several megacycles, the loop acts to stabilize against all important noise in the vicinity of the output carrier. This is performed in a manner which can support the high gain needed for noise suppression since the multiplier sections of the loop controlled stages are both unilateral and contribute loss - not gain - to the over all gain of the feedback system. As a result, Bode criteria for a stable servo circuit, even with high loop gain, are easily met, and wide band stabilization due to coherent noise accomplished.

In general, random noise cancellation or reduction should not be contributed by the system. Not enough work has been performed at this time for an evaluation of this effect of random noise, but there is evidence that a "phase-lock" effect similar to that in phase-locked VCO loop detectors may occur in which the servo system attempts to "lock" to the constant d.c. reference voltage whose noise content then becomes a determining noise parameter of the system

An actual power multiplier chain system was studied which provided output power of up to 100 mw in K-band starting from 55 mc oscillator. This chain detected power in K-band and actuated a wideband high gain feedback system driving a PIN diode attenuator positioned between immediate stages in C-band to provide an output signal with noise components comparable to or below KBT noise in the vicinity of the frequency of the output signal. By changing the magnitude of the reference voltage in the servo system, the output power could be controlled over a lower than 10 db range without effecting output signal purity.

## References


1. D. B. Leeson, "Instabilities in Varactor Multipliers," 1966 International G-MTT Symposium Digest.

2. M.E. Hines, "Microwave Power Sources using Varactor Harmonic Generation," Microwave Journal, April, 1963.

3. C.L. Cuccia, J. Napoleon, and D.E. Nelson, "Miniature C-band Solid-State Frequency Multipliers for Missiles," RCA Engineer, March - April, 1964, available as an RCA DEP Publication.

4. M.E. Hines and J.D. Ondria, "Theory and Measurements of Noise in Varactor Harmonic Generation Sources," 1966 International G-MTT Symposium Digest.

5. R.A. McConnell, "Phase Stability of Varactor Frequency Multipliers," 1964 PGMTT International Symposium Digest.

6. W.K. Victor and M.H. Brockman, "Application of Linear Servo Theory to the Design of AGC Loops", Proc. IRE, February, 1960.

7. I. Kaufman and D. Douthett, "Harmonic Generation using Idling Circuits," Proc. IRE, April 1960.

8. C.L. Cuccia, "Broadband Multiplier Chains with Interdigital Filters," MicroWaves, June, 1964.