

WME (IMS) Monday 08:00 – 17:00 BCEC Room 153C

Subharmonically Pumped Mixers (SHP mixers): Design Theory and Systems Applications

Full-day workshop reviewed by MTT-22, IMS09

Organizer(s):

Kenji Itoh, Mitsubishi Electric; MTT-22, IMS TPC.

Bert Henderson, Cobham Defense Electronic Systems, M/A-Com; MTT-22.

From early years of microwave engineering, the subharmonically pumped (SHP) mixer technique was used for the higher frequency bands because of the lower frequency local oscillator. In addition to this well-known historical fact, the SHP mixer technique is re-focused for new RF applications by its unique nature of spurious mixing products. In this workshop, following technical contents will be presented by experts in this field:

- History of the SHP mixer techniques
- Circuit theory
- Circuit design
- GaAs/Si implementations of SHP mixers
- RF system applications of SHP mixers from cellular phone to THz radio astronomy

Speakers:

1. Edmar Camargo, RF Micro Devices

“History of the Sub-Harmonically Pumped Mixer: from Tubes to CMOS”

Sub-harmonic mixers appeared in the early thirties as a solution to minimize LO radiation from super-heterodyne receivers, and to obtain higher effective LO frequencies. However, their overall performance were inferior to fundamental mixers, so they did not receive the attention they deserved. Despite the drawbacks, the concept revived over the years mainly caused by technology developments from tubes to Schottky diodes on Silicon, high frequency bipolar devices, GaAs FETs, and most recently Silicon CMOS FETs. In recent years the demand for wireless communications began favoring direct receiver approaches as a means to cut cost and LO radiation problem surfaced again. Fortunately, circuit technology also evolved over the years and modern sub-harmonic mixers now have acceptable performance levels allowing their application into wireless systems. This presentation gives an overview of the evolution of sub-harmonic mixers and reports on the important milestones of this technology.

2. Stephen Maas, AWR

“Theory of the Subharmonically Pumped Mixers”

In this presentation we discuss the theory of the subharmonically pumped (SHP) mixer and examine how that theory predicts some unusual aspects of its performance. SHP mixers (like all harmonic mixers) exhibit conversion loss vs. LO level behavior that is different from fundamentally pumped mixers, and their noise and distortion differ as well. In diode SHP mixers, these characteristics can be related directly to the junction

conductance and capacitance waveforms. In active mixers, the same phenomena occur but are related to transconductance waveforms instead of conductance.

3. Bert Henderson, Cobham Defense Electronic Systems, M/A-Com
“SHP mixer Circuit Designs”

Subharmonically pumped (SHP) mixers have been reported that use a wide range of device types, circuit topologies, and fabrication techniques. This presentation discusses the design process for diode and FET SHP mixers, giving a design example for both. Also, numerous important published SHM designs are discussed.

4. Kenji Itoh, Mitsubishi Electric
“RF Systems with Even Harmonic Mixers: Unique Spurious Nature”

The even harmonic mixer (EHM) was mainly used for millimeter wave receiving mixer in its history, with advantage of its halved local oscillator frequency. The EHM with an anti-parallel diode pair (APDP) is one of the effective technique to enhance its conversion efficiency and to achieve almost the same value as the fundamental mixer. In the APDP, even order mixing products including fundamental ones can be canceled in the APDP, and odd order mixing products are enhanced by signal power transfer by the cancel. In this presentation, extreme cancellation of the APDP is focused and following RF system applications with EHMs with APDPs: - Up-converter with low LO leakage, - QPSK modulator with low carrier leakage, - Direct conversion receiver with low even order products. The world-first W-CDMA direct conversion receiver with mass production achieved low all of 3GPP specifications by the even harmonic quadrature mixer with APDPs.

5. Carlos Saavedra, Queen's University, Canada
“CMOS Subharmonic Mixers and Applications”

The structure of CMOS x2 SHP mixers using a Gilbert-Cell multiplier topology will be reviewed and an analysis of the factors affecting conversion gain will be carried out. This mixer structure will subsequently be expanded in order to accommodate higher-order SHP mixing circuits. Such higher-order mixers exhibit exceptionally good port-to-port isolation and can have good conversion gain as compared with diode-based designs. The talk will conclude with a discussion of odd-integer frequency multiplication using SHP mixers.

6. Tsuneo Tokumitsu, Eudyna
“Design and Implementation of SHP Mixer in the 3-D MMIC”

The sub-harmonically pumped (SHP) mixer has simple topology and requires a low LO frequency ($f_{RF}/2$), while it needs quarter-wavelength lines for fLO to electrically short the fLO and 2fLO signals. To effectively use the simplicity and the 2fLO suppression

nature, some SHP mixers were implemented in our 3-D MMIC structure, successfully shrinking the circuit area to less than 0.3 mm². An SHP image-rejection mixer is composed of a pair of SHP, a 90-degree broadside coupler with additional 45-degree transmission line, and a Wilkinson divider. A layout of these components were compactly performed in an area of less than 1.0 mm², while a high LO power level required to increase IP1dB. On the other hand, a multiplier chain can be easily integrated in the 3-D MMIC. When lower phase noise and highly linear mixer performance is required, selection of mixer type, SHP or resistive mixer, is an important issue. A 77GHz balanced resistive mixer will also be shown to discuss on the mixer types.

7. Erich Schlecht, JPL

“THz SHP Mixers for Planetary, Earth, and Astronomical Observations”

Since the mid 1970s subharmonically pumped Schottky diode mixers have been developed, in the submillimeter wave and Terahertz range. One application has been astronomical observations, especially for spectroscopy. As Schottky mixers are especially attractive for all systems needing minimum mass, and no cryo-cooling, a prime example being space-based applications. The 1990s saw the development and launch of the Submillimeter-Wave Astronomy Satellite (SWAS) in 1998. In this decade, the Earth-observation Microwave Limb Sounder (MLS) was launched on the AURA spacecraft in 1994, as was ESA's Rosetta, a comet-bound craft carrying the MIRO instrument This presentation will present the history of SHP submillimeter Schottky mixers, including their initial development, as well as their astronomical and space-based applications. In addition, the basics of submillimeter SHP operation, design and fabrication will be shown, including current research and future directions.

8. Zhiyang Liu, Tyco Electronics

“High-Order Subharmonically Pumped Mixers Using Phased Local Oscillators”

High-order subharmonically pumped mixer architectures that utilize multiple pairs of antiparallel diodes are described. The key component of the mixer architecture is a K-way power-divider/phase shifter that divides the local oscillator (LO) to multiple ports with equal magnitude and prescribed phase shifts. Undesired mixing products are eliminated through phase cancellation by symmetry rather than relying on intermediate idler circuits. The mixer architecture is suitable for applications in the millimeter and submillimeter-wave regions where high-frequency LOs are difficult to implement.