ACTIVE CPW-FED SLOT ANTENNAS FOR POWER COMBINING APPLICATIONS

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ABSTRACT

We have combined integrated circuit antenna technology with microwave oscillator design to build an active slot-oscillator. The design is planar, does not require via holes and is compatible with monolithic transistor technology. The CPW-fed antenna impedance is calcualted using a full-wave analysis technique. Slot-oscillators were built at 7, 13, and 22 GHz and the predicted oscillation frequencies agree well with experiments. The design is easily scaled to millimeter-wave frequencies and can be extended to power combining arrays.

INTRODUCTION

Millimeter-wave systems are becoming increasingly important in many military and commercial applications. Millimeter-wave receivers and transmitters have been traditionally waveguide-based systems and these are expensive to build at these frequencies. To solve this problem, several groups researched quasi-optical power combining topologies and active antennas [1-4]. In this paper, we present a novel active transmitter suitable for low-cost millimeter-wave applications. The transmitter consists of a cpw-fed slot antenna (or a dual-slot antenna) on a high-dielectric substrate- lens and a three-terminal device (millimeter-wave HEMT). The novelty in this approach is that we use the antenna impedance, calculated by a full-wave analysis method, as a parameter in the design of the oscillator. This results in a much more compact circuit than the conventional approach which consists of an oscillator with a 50Ω output that is matched to a radiating slot-antenna. In our design, the matching network is eliminated (or minimized), the circuit is much smaller than a wavelength and this allows the design of a power combining array without trigerring grating lobes. The design can be easily scaled to millimeter wavelengths when HEMT transistor technology is available at these frequencies.

OSCILLATOR DESIGN AND MEASUREMENTS

The oscillator design is based on the S-parameters of the transistor used. An indefinite scattering matrix is employed so that short circuited lengths of CPW may be placed at the gate and source. Computer optimization is then applied to the lengths of CPW to maximize the reflection coefficient at the drain of the device. In this way a reflection magnitude greater than one is obtained without the use of an external feedback network and its associated complications. A slot antenna is connected to the drain through a length of CPW. In order for oscillations to build up, the impedance the slot antenna presents to the drain must have a reflection coefficient magnitude at least as large as the reciprocal of the reflection coefficient at the drain and the phase must be opposite in sign. The impedance of the CPW fed slot-antenna on a substrate must be well known and is calculated by a full wave moment method analysis. The terminals of the FET are DC isolated from eachother to allow bias voltages to be applied. This is done by integrating metal-insulator-metal capacitors and bypassed slits in the ground plane.

Slot-oscillators were designed and built at 13GHz and 22GHz (Fig 1.) using commercially available hetero-junction FETs (NE32100, NE32184). The circuits oscillated near the predicted frequency when placed at the focus of a one inch diameter elliptical silicon substrate lens (Fig. 1). The radiation patterns of the oscillators on the substrate lens were measured (Fig. 2) and are used to estimate the directivity. Total oscillator power is calculated with the radar equation. The total radiated power measured was 5.4mW at 13.01GHz and 3mW at 22.45GHz. The DC to RF efficiency is 5.4% at 13.01GHz and 3.8% at 22.45GHz. These numbers are consistent with the capability of the transistor which is a low noise small signal devices operated at maximum bias. In the future medium power transistors will be used.

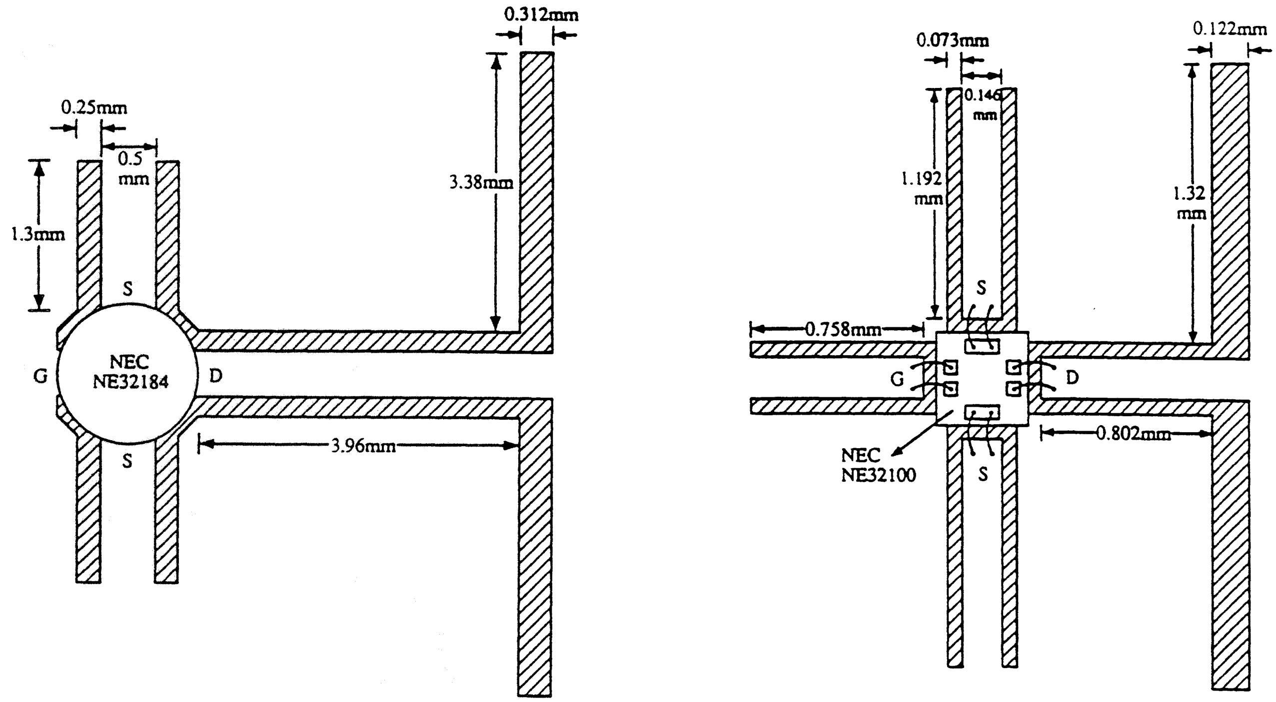

Figure 1: 13GHz and 22GHz slot-oscillator designs.

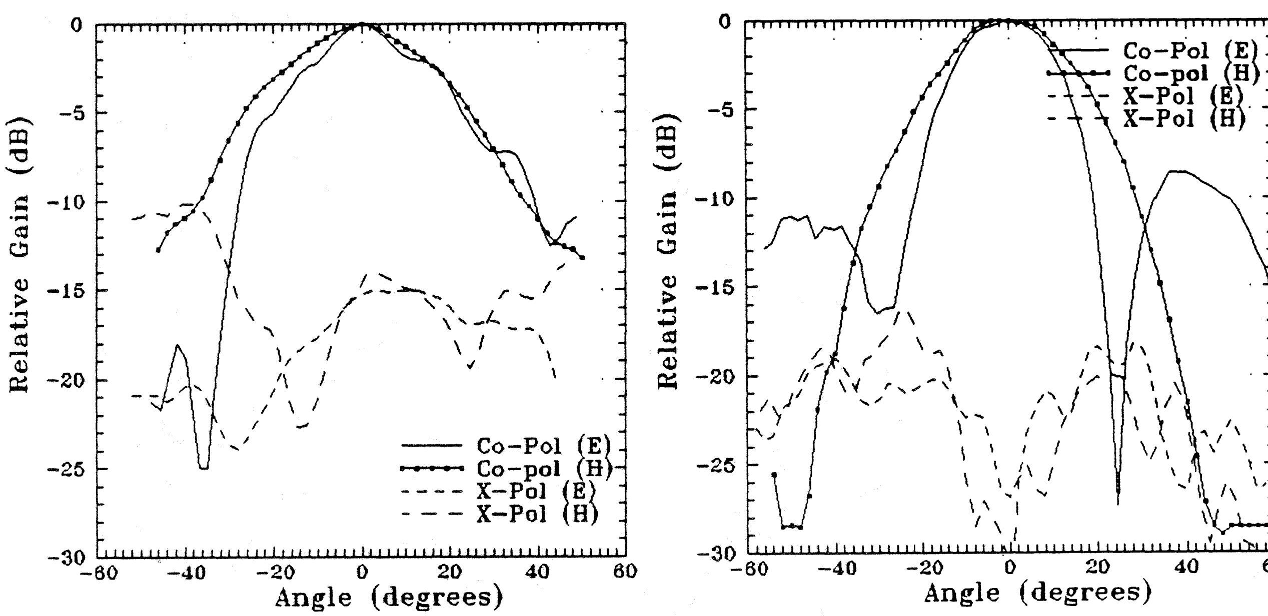

Figure 2: Radiation patterns of 13GHz and 22GHz slot-oscillators on one inch diameter silicon substrate lens.

A 7GHz VCO (Fig 3.) was designed using the above method with the incorporation of varactor diodes (Metelics MSV34-60-E28) at the source terminals of the FET. An oscillator tuning range of 850MHz was achieved from 6.68GHz to 7.35GHz. This shows that electronically tunable slot-oscillators are possible for phase locked loops or other applications.

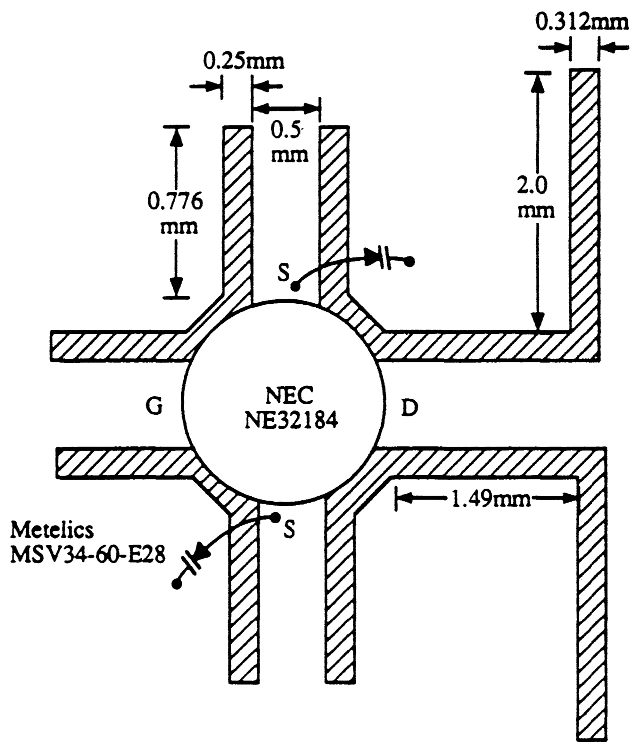

Figure 3: 7 GHz VCO with 850 MHz tuning range

The oscillators are well suited for use in power combining arrays synchronized by the mutual coupling between antennas. One possible array configuration (Fig. 4) is to place a two dimensional array on a dielectric block of quarter wavelength thickness. Most of the power will radiate out the opposite side of the block. A weak substrate mode will exist in the block and may enhance the mutual coupling. If neccessary a reflector may be used on the back side of the block to further enhance mutual coupling and improve phase equalization between elements.

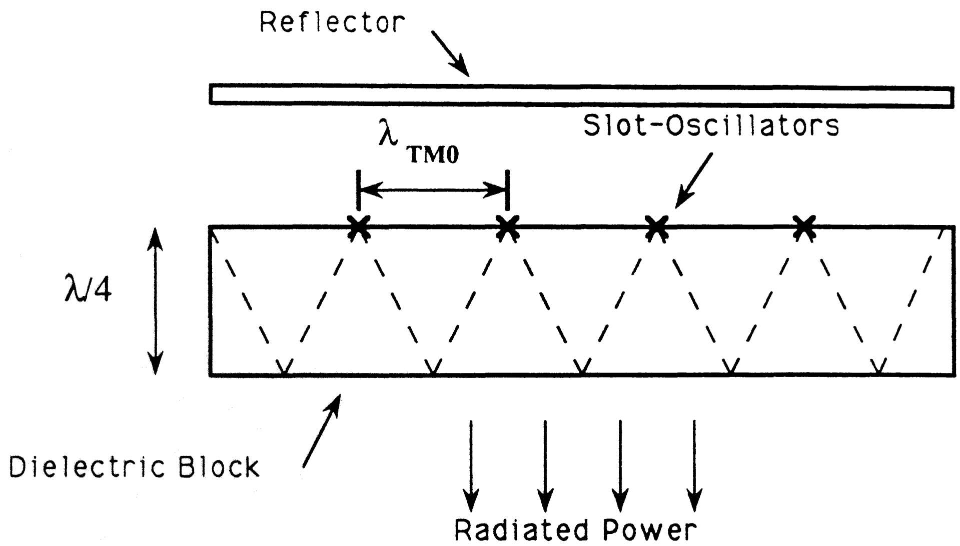

Figure 4: Possible slot-oscillator array configuration

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