A CIRCULARLY POLARIZED FET OSCILLATOR ACTIVE RADIATING ELEMENT

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ABSTRACT

We present an FET oscillator which combines the power from three devices and directly generates circularly polarized radiation using a novel feedback arrangement. The radiated field exhibits a minimum axial ratio of 1.04. This oscillator is suitable for use in spatial power combining systems or as an active antenna when injection locked from an external source.

INTRODUCTION

The use of radiating FET oscillators for spatial power combining and as elements of active antennas has been reported in [1-5]. The typical oscillator in these systems consists of a negative resistance element, such as a Gunn diode or an FET in an unstable configuration, connected to a radiating resonator, such as a microstrip patch.

In this paper we report an FET oscillator which radiates a circularly polarized wave. In contrast to the resonant antenna approach, this oscillator is made up of three microstrip single-FET amplifiers which are connected in series, with their outputs coupled to rectangular patch antennas. This arrangement provides for convenient application of an external locking signal at the input of one of the amplifiers.

CIRCUIT DESCRIPTION

A diagram of the oscillator circuit is shown in Figure 1, with a detail of the individual FET amplifier in Figure 2. The individual amplifiers are connected "head to tail" in a closed circuit using directional couplers, which couple a small portion of the output of one amplifier to the next amplifier in line. The output of each amplifier is connected to a patch antenna through the direct port of the coupler.

Since the amplifiers are identical, they have equal outputs with phases of 0 degrees, 120 degrees, and 240 degrees. These outputs are then fed to individual antennas which are oriented at 0 degrees, 120 degrees, and 240 degrees, respectively, causing the radiated power to be polarized circularly.

An external injection signal may be applied to the input of one of the amplifiers in the loop. This type of injection locked oscillator is a variation of the "transmission type" oscillator described by Tajima [6]. When compared to the negative resistance approach, this configuration affords a substantial increase in locking bandwidth [6]. In addition, this injection port may be used to interconnect an array of oscillators [7].

OSCILLATION CONDITION

For the purpose of analysis, the oscillator is divided into three identical sections, each consisting of an amplifier, coupler, and patch antenna, as shown in Figure 2. The oscillation condition is given by:

$$\det(\Gamma - S) = 0$$

where S is a block diagonal matrix whose elements are the s matrices for each identical section,

$$S = \begin{bmatrix} \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} & 0 & 0 \\ 0 & \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} & 0 \\ 0 & 0 & \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \end{bmatrix},$$

and Γ describes the network connections [8],

$$\Gamma = \begin{bmatrix} 0 & \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix} & \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \\ \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} & 0 & \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix} \\ \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix} & \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} & 0 \end{bmatrix}.$$

If the amplifiers are unilateral, ($s_{12} = 0$), the result is:

$$1) \quad (s_{21})^3 + 3(s_{11}\,s_{22}) - 3(s_{11}\,s_{22})^2 + (s_{11}\,s_{22})^3 - 1 = 0$$

In this expression, the s-parameters are dependent on the amplitude as well as the frequency of the scattered waves.

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CIRCUIT DESIGN

The design of the oscillator proceeds by first constructing one of the amplifiers, including the output coupler and patch antenna, using small signal techniques. The circuit is designed to have 120 degrees of phase shift, and a gain of 3 to 4 dB (including coupler loss) at the desired operating frequency, in this case 6 GHz.

These amplifiers were constructed on .031 inch thick woven glass reinforced PTFE substrate, using Avantek 26884 packaged FETs. Each antenna consisted of a 1.0x1.0 inch piece of 0.125 inch thick polyethylene which had a 0.6x0.4 inch rectangular metallized patch on one side. This polyethylene antenna was then attached to the backside metallization of the .031 inch substrate using double-sided foam tape, creating a microstrip-type structure. Connections between the amplifier and the antenna were made using via holes.

The large signal S parameters for this section of the oscillator were then measured using a modified HP 8410 vector network analyzer, with input power in the range of -10 to +7 dBm. The variation of s_{21} and s_{11} with input power level are shown in Figure 3. Input drive levels were assumed to have little effect on s_{22} due to the isolation of the coupler; s12 was negligible. These data were used in Equation 1 to determine the operating point of the oscillator.

OSCILLATOR PERFORMANCE

The circuit oscillated at a frequency of 5.961 GHz, which was less than one percent from the predicted value of 5.982 GHz derived from Equation. 1 and the data shown in Figure 3. This primarily indicates the repeatability of the construction procedure. Radiation patterns are shown in Figure 4, with axial ratios shown in Figure 5 for two perpendicular planes. Injection locking range as a function of injected power is shown in Figure 6.

The ERP for this oscillator is 24.6 dBm at a bias of 5V Vds and Ids = 110 mA. This corresponds to an isotropic conversion gain of 0.2 dB [9].

The low axial ratio in the vicinity of boresight indicates the balance of the oscillator. The three patch antennas were spaced about 3/4 lambda apart, for ease of construction. This relatively large antenna spacing resulted in the degradation of axial ratio away from boresight. Replacing these three antennas with a more compact three port radiator, such as a single three arm end-fed spiral, should decrease the axial ratio away from boresight when operation in this region is desired.

CONCLUSION

We have demonstrated a radiating FET oscillator which combines the power of three devices in a single circularly polarized beam. Because of its "transmission-type" configuration, it exhibits a broad injection locking range. This makes it useful as an element of an active antenna, where several such oscillators would be locked to a modulated signal. The injection locking signal would be orders of magnitude lower than the corresponding drive level for a passive antenna.

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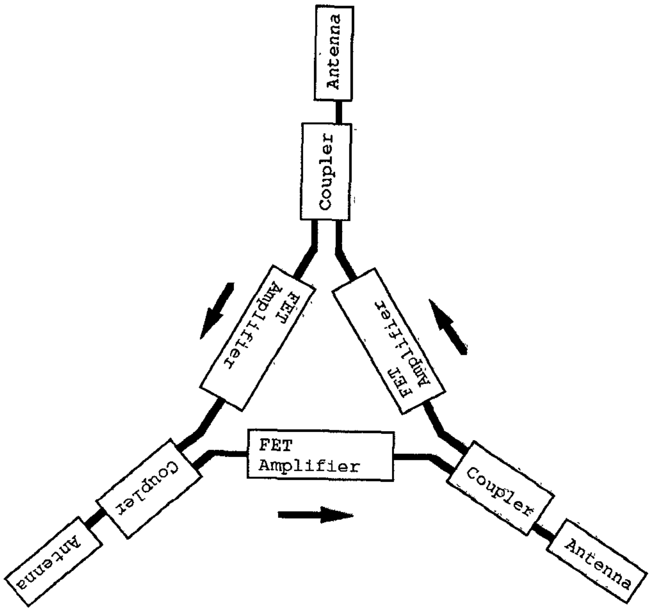

Figure 1. Block diagram of oscillator. Arrows indicate signal flow.

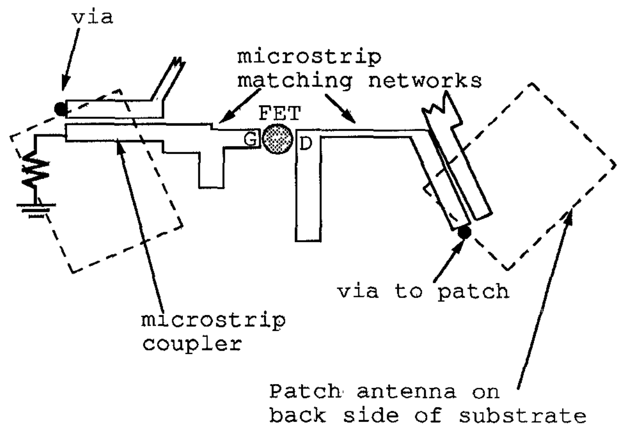

Figure 2. Detail of one-third of the oscillator, showing amplifier, coupler, and patch.

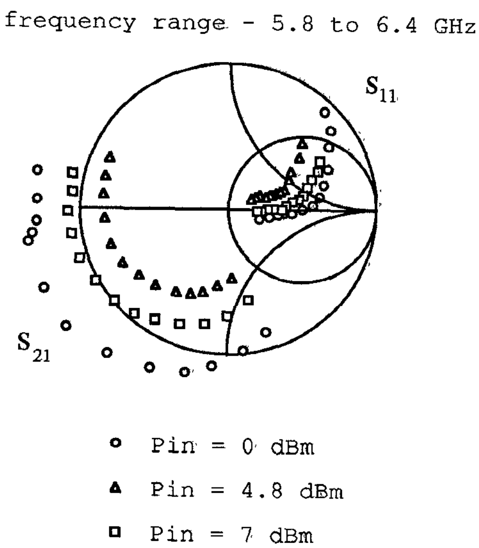

Figure 3. Scattering parameters for the circuit shown in Figure 2, as a function of input power.

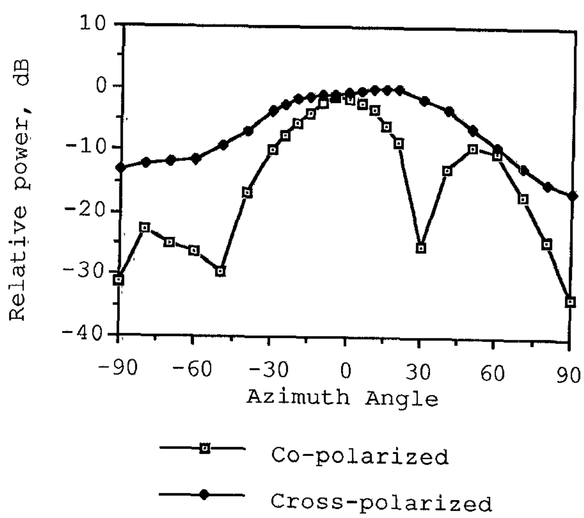

Figure 4. Co-polarized and cross-polarized radiation components.

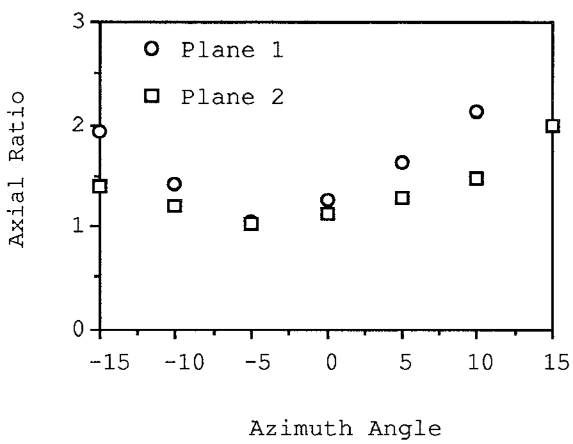

Figure 5. Axial ratio for two perpendicular planes.

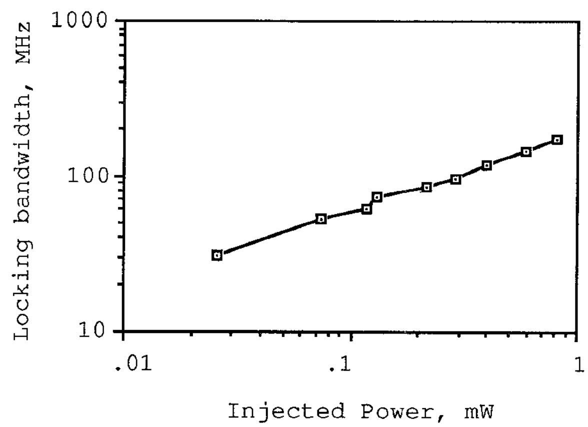

Figure 6. Locking bandwidth versus injected power.