PLANAR DIELECTRIC RESONATOR STABILIZED HEMT OSCILLATOR INTEGRATED WITH CPW/APERTURE COUPLED PATCH ANTENNA

Rainee N. Simons and Richard Q. Lee

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

Abstract

A new design of an active antenna with a dielectric resonator stabilized HEMT oscillator (DRO) and an aperture-coupled patch antenna is reported. The circuit is fabricated using coplanar waveguide (CPW) with the oscillator and the antenna on opposite sides of the substrate. The active antenna was demonstrated at 7.6 GHz; however, the design can be scaled to higher frequencies. Excellent oscillator characteristics and radiation pattern have been obtained.

I. Introduction

As the frequency of operation of Earth observation systems (EOS) shifts into the millimeter wave and submillimeter wave regions of the spectrum, there is a need to develop efficient power combining techniques which can eliminate circuit losses, minimize expensive machining of mounts and housing for diodes, reduce thermal problems, provide graceful degradation and combine large number of active devices. Conventional low frequency power combining techniques are unable to meet the above requirements, and hence quasi-optical or spatial power combining have to be employed. In the past, a quasi-optical integrated antenna and receiver front end was demonstrated using MESFET oscillator coupled to a slotline-coplanar waveguide antenna.[1] A wideband tunable active antenna and power combiner was also demonstrated using a Gunn diode mounted in a slotline-coplanar waveguide resonator.[2]

In this paper, we demonstrate a new design of an active antenna module with a dielectric resonator stabilized HEMT oscillator (DRO) which is aperture-coupled to a patch. Several of these modular antennas can be combined to form a spatial power combiner. The circuit is fabricated using coplanar waveguide (CPW) with the oscillator and the patch antenna on opposite sides of a two-layer dielectric substrate. By fabricating the antenna and the oscillator on two substrates of different permittivity and thickness, both of these components can be independently optimized for best performance.

II. Design Description and Fabrication

Oscillator

Figure 1 shows the schematic of a DRO with series feedback. In this circuit Γ_g and Γ_r are the reflection coefficient looking into the gate terminal of the HEMT and the input terminal of the transmission line coupled to the dielectric resonator respectively. Γ_g is written as[3]

$$\Gamma_g = S_{11} + S_{12}S_{21}\Gamma_L \times (1 - S_{22}\Gamma_L)^{-1}. \quad (1)$$

Where S_{11}, S_{12}, S_{21}, and S_{22} are the scattering parameters of the HEMT with a transmission line of length d_s connected in series with the source to provide feedback, and Γ_L is the reflection coefficient of the load connected to the drain. Γ_r is written as

$$\Gamma_r = \Gamma_c \exp\left(-j\,\frac{2\pi d_g}{\lambda_g}\right). \quad (2)$$

Where Γ_c is the reflection coefficient at the reference plane of the resonator which is at a distance d_g from the gate. Γ_c takes into account the coupling coefficient β and the termination Z_0. The condition for steady state oscillation to occur in the circuit can be written as[3]

$$\Gamma_g\Gamma_r = 1. \quad (3)$$

To fabricate the oscillator, the length d_s which provides the series feedback is adjusted so that the HEMT is unstable, that is, $|\Gamma_g|$ should be greater than unity. The location d_g of the dielectric resonator with respect to the gate is adjusted so as to satisfy Eq. (3). The CPW circuit layout for the oscillator part of the active antenna is shown in Fig. 2. The circuit is fabricated on 0.635 mm thick RT/Duroid 6010.5. The active device is a low noise HEMT (Model S8902) manufactured by Toshiba. The dielectric resonator (Part no. TC-8500-x-001) is manufactured by Trans-Tech, Inc.

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Antenna

Figure 3 illustrates the CPW aperture-coupled patch antenna part of the active antenna. The coupling takes place through an aperture in the common ground plane separating the CPW and the patch. The aperture width W_2 of 0.254 mm is chosen for ease of fabrication. A good initial guess for the aperture length L_2 is $\lambda_{g(slotline)}/2$, where λ_g is the wavelength of an uniform slotline. This starting value of L_2 is then slightly reduced to account for the slot end effects. To improve coupling a notch of width W_1 (0.75 mm) and length L_1 is cut out from the CPW ground plane located right above the aperture. The longitudinal distance between the extreme ends of the notches is slightly less than the aperture length L_2. The CPW is terminated in a short circuit at a

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distance of approximately $\lambda_{g(cpw)}/2$ from the center of the notch. The length A of the patch is less than half wavelength after correcting for end effects. The width B of the patch is 1.5 times A. To improve coupling the aperture is offset by about 5.5 mm from the center of the patch. The feed and the patch are fabricated on 0.508 and 0.254 mm thick RT/Duroid 5880 respectively.

III. Experimental Results and Discussions

The measured frequency spectrum at 7.6 GHz of the active antenna is shown in Fig. 4. The stability of oscillations is excellent. The measured *H*-plane radiation pattern of the active antenna is shown in Fig. 5 and is observed to be typical of a patch. The measured cross-polarization is less than -20 dB. By substituting the measured power and gain into the Friis transmission formula the absolute power radiated by the patch antenna is determined to be 1.1 mW. This is small since the HEMT is a low-noise low-power device.

IV. Conclusions

An active antenna with a dielectric resonator stabilized HEMT oscillator and a CPW/aperture coupled patch antenna is presented. Although the active antenna is demonstrated at 7.6 GHz, the design can be easily scaled to higher frequencies. Excellent oscillator characteristics and radiation pattern have been obtained.

References

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2. J.A. Navarro, Y.H. Shu, and K. Chang, "Wideband integrated varactor-tunable active notch antennas and power combiners," IEEE MTT-S International Microwave Symposium Digest, New York: IEEE, 1991, vol. 3, pp. 1257-1260.

3. G.D. Vendelin, A.M. Pavio, and U.L. Rohde, Microwave Circuit Design Using Linear and Nonlinear Techniques. New York: John Wiley & Sons, 1990, Chap. 6.

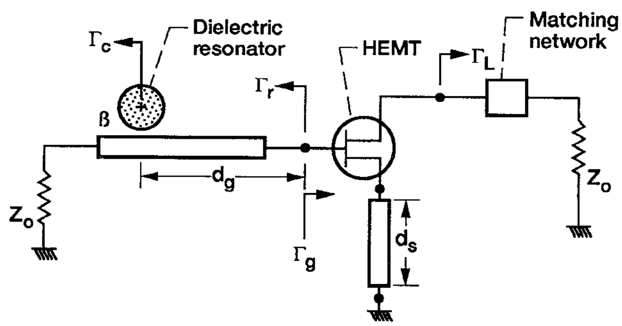

Figure 1.—Schematic of a dielectric resonator stabilized HEMT oscillator with series feedback.

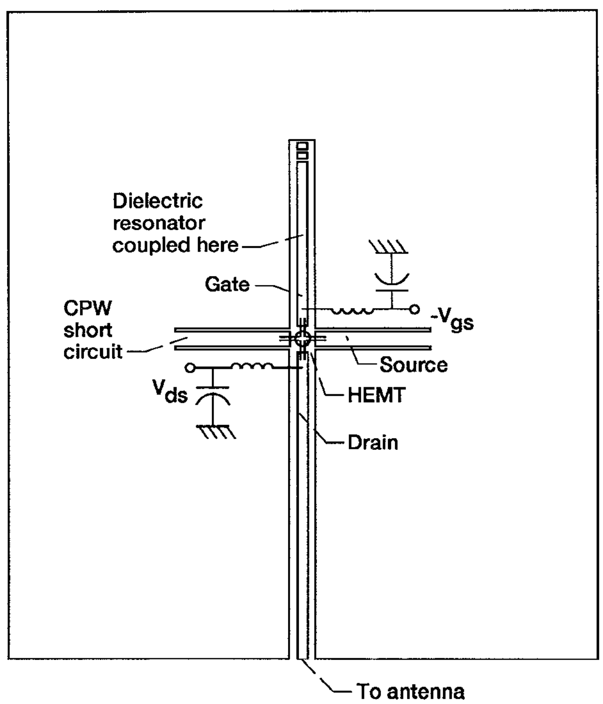

Figure 2.—CPW circuit for the oscillator part of the active antenna.

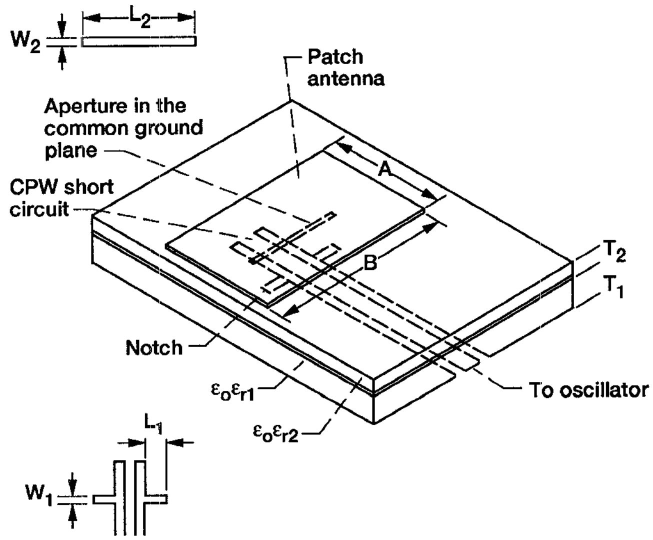

Figure 3.—Schematic illustrating the CPW aperture-coupled patch antenna part of the active antenna.

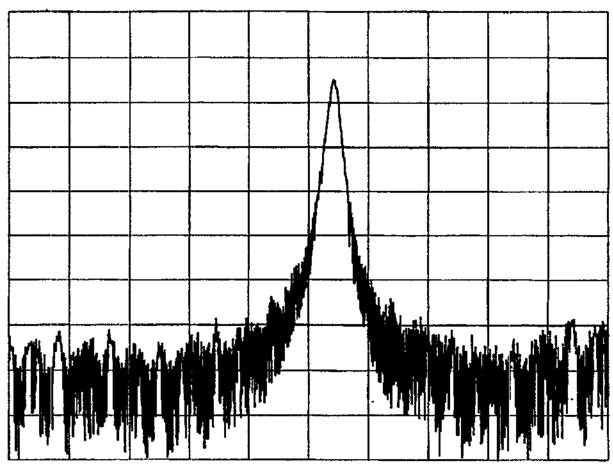

Figure 4.—Measured frequency spectrum of the oscillator. Center frequency is 7.6 GHz, Res. BW = 100 kHz, Hor. div = 1 MHz, Ver. div = 10 dB.

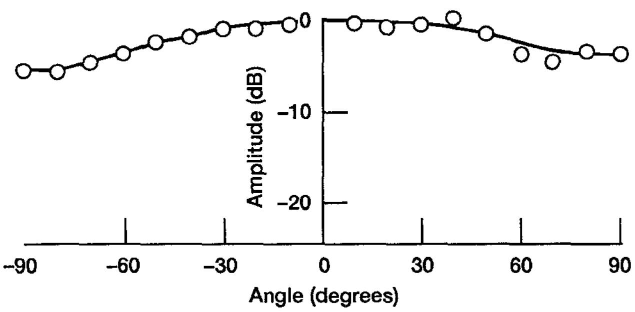

Figure 5.—Measured far field H-plane radiation pattern of the active antenna.