

A Dual-Beam Asymmetrically Scanning Leaky-Wave Antenna by Utilizing a HEMT Resistive Upconverter

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Abstract—A dual-beam asymmetrical scanning microstrip leaky-wave antenna (LWA) has been demonstrated in this paper. A HEMT resistive upconverter output is connected to one terminal of the LWA, and a local oscillator (LO) signal is connected to the other terminal. In this experiment, we set the LO frequency at 9.5 GHz so that the right beam is fixed at 48°. By changing the IF frequency from 0.7 GHz to 1.5 GHz, the module of the LWA can steer the left main beam of the far-field pattern from 136° to 158° (the total scanning angle of 22°). Comparisons between the measured and theoretical results indicate that the design can achieve the asymmetrically scanning capability and agree well over the tuning bandwidth of 0.8 GHz.

Index Terms—Dual-beam asymmetrically scanning, resistive up-converter.

I. INTRODUCTION

MICROSTRIP leaky-wave antennas [1]–[4] have the advantages of narrow beamwidth, small size, easy fabrication, easy matching, frequency scanning, and can be easily integrated with other useful circuits (such as an amplifier [1], a VCO [2], a switch circuit [3]) on the same substrate to be used in communication systems. Recently, some researches have successfully achieved dual-beam symmetrically scanning capability [2]–[4]. However, in many physical applications such as position calibration systems, one beam is fixed at some angle, and the other beam needs to be steered to locate a specified object with relative position to the observer. Traditional dual-beam scanning antennas fail to meet the requirement in these applications.

This paper details the design of a two-terminal leaky-wave antenna [2] integrated with a HEMT resistive upconverter (see Fig. 1). If the IF port has no injection, the proposed topology can perform the conventional dual-beam symmetrically scanning function just by changing the LO frequency. In addition, fixing the LO frequency and varying the IF frequency, we can derive the dual-beam asymmetrically scanning radiation patterns.

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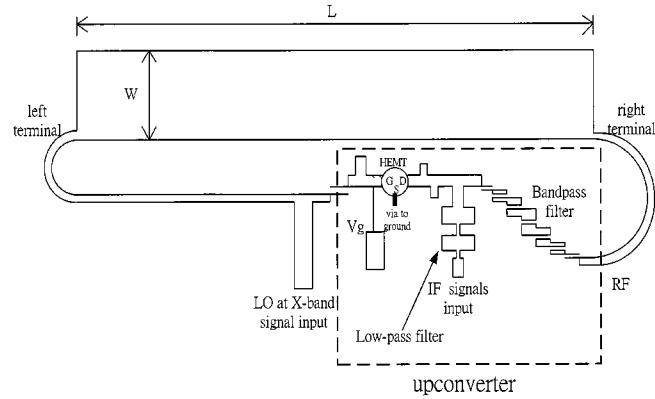


Fig. 1. Configuration of a two-terminal feeding leaky-wave antenna integrated with a resistive HEMT upconverter.

II. DESIGN

Fig. 1 shows the configuration of the X-band dual-beam asymmetrically scanning leaky-wave antenna. The circuit consists of a *T*-type power divider, a HEMT upconverter and a microstrip leaky-wave antenna with a two-terminal feeding structure. All components mentioned above are fabricated on a RT/Duroid substrate with the thickness of 0.508 mm and the dielectric constant of $\epsilon_r = 2.2$. A NEC NE42484C low-noise HEMT serves as a frequency-mixing device of the upconverter. The HEMT device is chosen for the consideration of lower noise performance and better conversion gain in comparison with a diode [5]. Additionally, the device also has the advantages of low cost and well integration with monolithic IC (MIC) in the future.

To excite the first higher order mode, the leaky-wave antenna is fed asymmetrically. The geometry and coordinate system for the microstrip LWA are shown in Fig. 2. Both of the RF and LO signals radiate the same field as a magnetic dipole with the magnetic current density $\underline{M}_s = -\underline{n} \times \underline{E}$. In order to realize the radiation characteristics of the microstrip LWA, we analyzed its normalized complex propagation constant $\beta/k_0 - j\alpha/k_0$ of the first higher order mode in the radiation region, where β/k_0 is the normalized phase constant and α/k_0 is the normalized attenuation constant. Fig. 3 shows the normalized complex propagation constant as a function of frequency, which was obtained by employing the rigorous (Wiener-Hopf) solutions mentioned in [6]. When $\beta/K_0 < 1$, the power of the input signal will leak in the form of the space wave in addition to the surface wave.

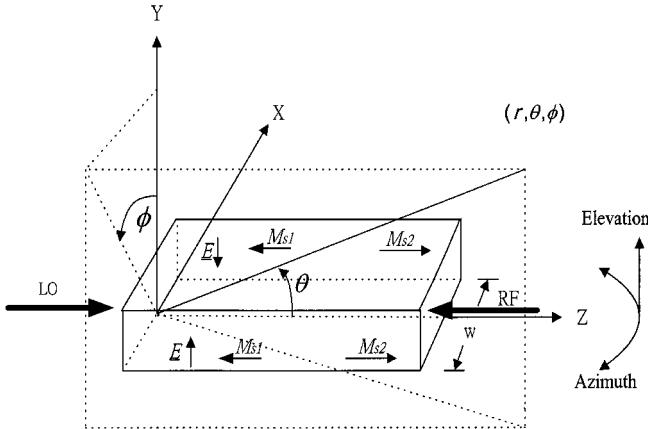


Fig. 2. Geometry and coordinate system for the microstrip LWA.

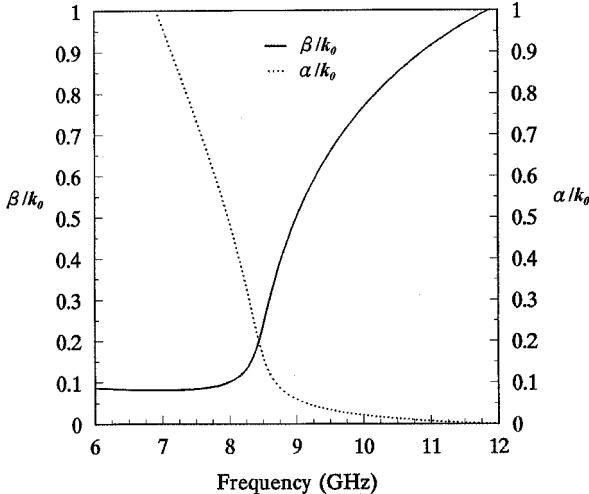


Fig. 3. Normalized complex propagation constants varied as a function of frequency.

III. THEORETICAL AND EXPERIMENTAL RESULTS

The resistive HEMT upconverter includes three ports (LO, IF, RF), where LO and IF are the input ports and RF is the output port. The LO frequency was set at 9.5 GHz (the X band). The IF frequency was varied from 0.7 GHz to 2 GHz (the UHF band). The RF output signal was obtained at the drain via the band-pass filter. The RF frequency range was from 10.2 GHz to 11.5 GHz (the X band). Fig. 4 showed the RF output power as a function of the bias voltage when the frequencies at the IF and the LO ports were 1.0 GHz and 9.5 GHz, respectively. The power of the IF and the LO was approximately 12 dBm and 0 dBm. The maximum output power at the RF port was close to -5.17 dBm when the gate voltage was biased at the range from -0.4 V to -0.3 V. The bandpass filter was used to extract the RF signal and also excluded the spurious frequencies of (LO and IF). Fig. 5 showed the RF power as a function of IF frequency when the LO power was at 0 dBm and the IF power was at 12 dBm. Fig. 6 showed the conversion loss of the HEMT upconverter when the LO power was 0 dBm at 9.5 GHz and the IF frequency was at 1 GHz. The 1dB compression point was approximately 12 dBm. Figs. 7-9 illustrated the simulated and measured dual-beam asymmetrically scanning radi-

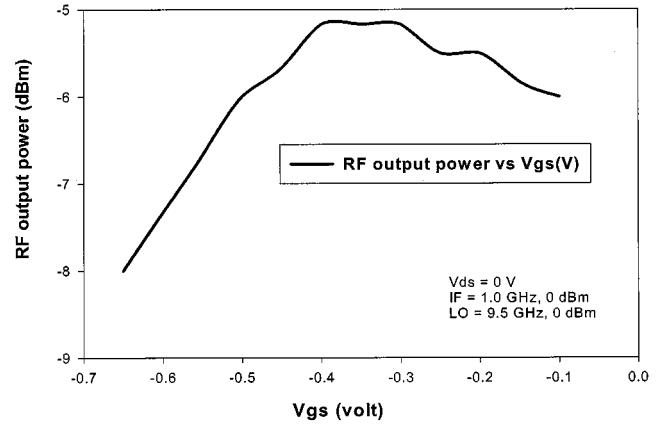


Fig. 4. Measured RF output power as a function of reverse gate bias.

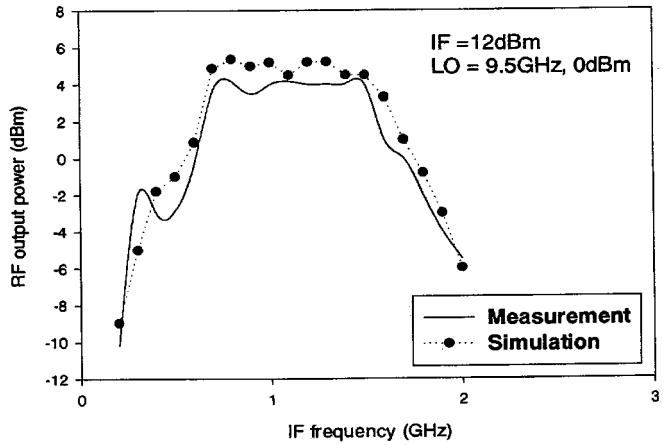


Fig. 5. Measured and simulation RF output power as a function of IF frequency.

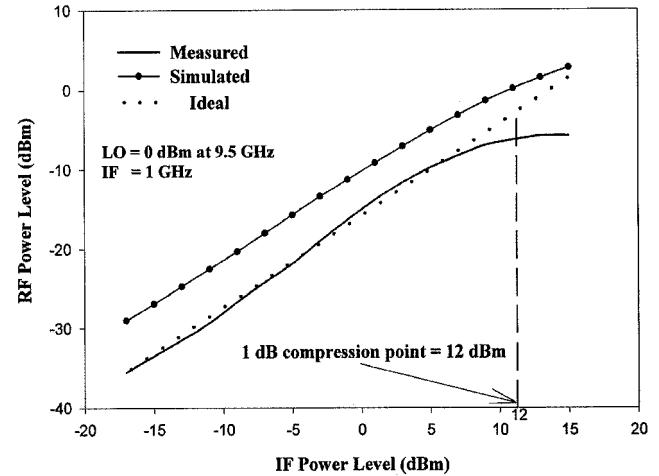


Fig. 6. Conversion loss of the HEMT upconverter.

ation patterns as the LO frequency was fixed at 9.5 GHz and the RF signal was varied at the three frequencies of 10.2 GHz, 10.5 GHz and 11.0 GHz. The theoretical radiation patterns for this dual-beam asymmetrically scanning leaky-wave antenna were determined by taking the data in Fig. 4 into the electrical field in [2, eq. (1)]. The calculated angle for the right beam at the LO frequency (9.5 GHz) was 47.5° , and those for the left beam were 137° , 144° , and 156° at three frequencies of 10.2 GHz,

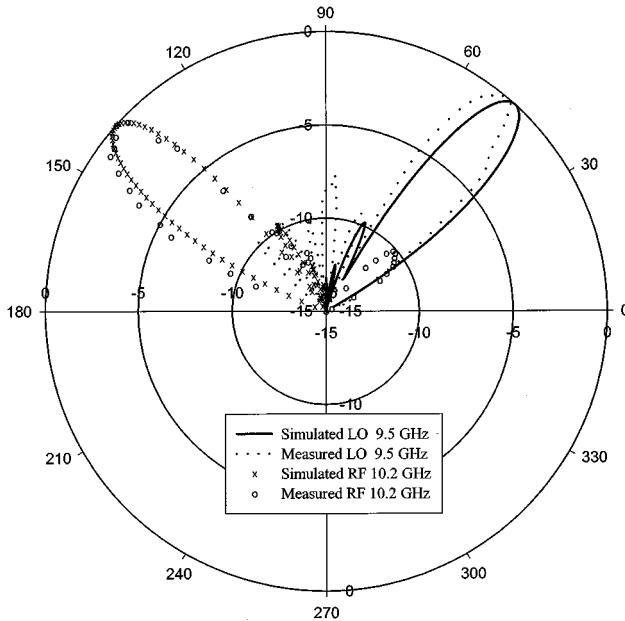


Fig. 7. Dual-beam asymmetrically scanning radiation patterns for the RF signal at 10.2 GHz when the LO signal is fixed at 9.5 GHz.

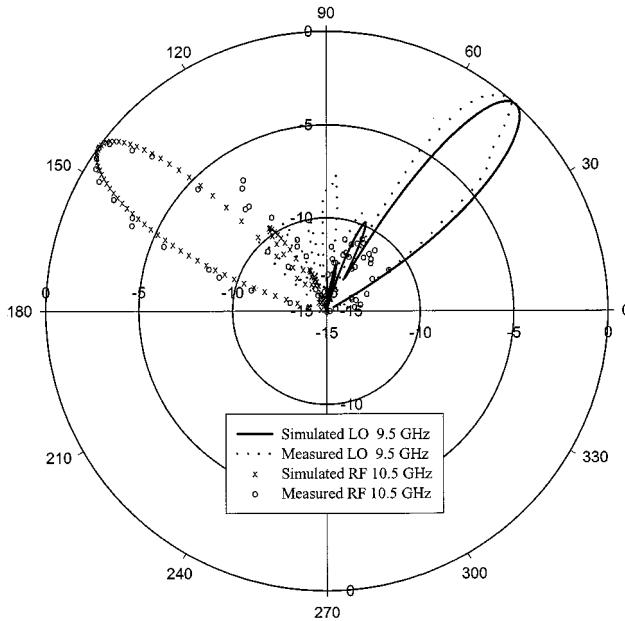


Fig. 8. Dual-beam asymmetrically scanning radiation patterns for the RF signal at 10.5 GHz when the LO signal is fixed at 9.5 GHz.

10.5 GHz and 11.0 GHz for the RF signal, respectively. The maximum effective isotropic radiated power (EIRP) was close to 18.96 dBm for the right beam at 9.5 GHz and 19.96 dBm for the left beam at 10.5 GHz. The angle of the right beam was measured of 48° controlled by the operating frequency at the LO port. The left beam should scan from broadside to end-fire as the RF frequency varied from 10.2 GHz to 11.0 GHz. The scanning angles of left beams were measured of 136° , 144° and

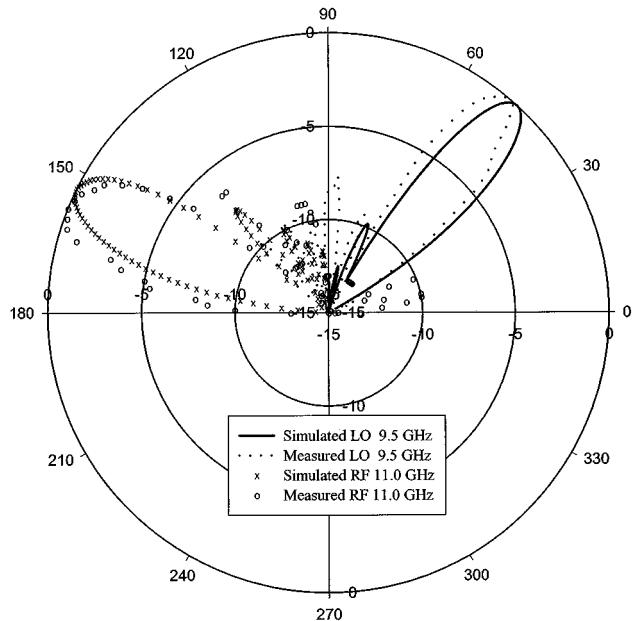


Fig. 9. Dual-beam asymmetrically scanning radiation patterns for the RF signal at 11.0 GHz when the LO signal is fixed at 9.5 GHz.

158° (the total angle of 22°), respectively, in accordance with the increment of the RF frequency. Good agreement between the theoretical predictions and the measured results for the proposed LWA performance was obtained.

IV. CONCLUSION

A novel dual-beam asymmetrically scanning leaky-wave antenna is illustrated in this paper. Experimental result reveals that the radiation patterns agree well with the expected patterns. The left beam scans around 22° while the right beam is fixed. The topology can provide multifunction of dual-beam symmetrically/asymmetrically scanning patterns and is suitable for automobile radar systems and satellite communication systems. We also can utilize the function of this structure to achieve calibration in wireless communication systems.

REFERENCES

- [1] G. J. Chou and C. K. Tzang, "Oscillator-type active-integrated antenna: The leaky-mode approach," *IEEE Trans. Microwave Theory Tech.*, vol. 44, pp. 2265–2272, Dec. 1996.
- [2] C. J. Wang, C. F. Jou, and J. J. Wu, "A Novel two-beam scanning leaky-wave antenna," *IEEE Trans. Antennas Propagat.*, vol. 47, pp. 1314–1317, Aug. 1999.
- [3] C. J. Wang, C. F. Jou, and Y. C. Shih, "A beam-switchable scanning leaky-wave antenna," *Electron. Lett.*, vol. 36, no. 7, pp. 596–597, Mar. 2000.
- [4] C. Luxey and J. M. Laheurte, "Simple design of dual-beam leaky-wave antennas in microstrips," in *Proc. Inst. Electr. Eng. Microwave, Antennas Propagat.*, vol. 44, Dec. 1997, pp. 397–401.
- [5] J. L. M. Lord and J. L. Fikar, "FET upconverter design using load dependent mixing transconductance," *IEEE MTT-S Dig.*, vol. 2, pp. 1089–1092, Dec., 1988.
- [6] D. C. Chang and E. F. Kuester, "Total and partial reflection from the end of a parallel-plate waveguide with an extended dielectric loading," *Radio Sci.*, vol. 16, pp. 1–13, Jan.–Feb. 1981.