V-BAND SINGLE CHIP, DIRECT CARRIER BPSK MODULATION TRANSMITTER WITH INTEGRATED PATCH ANTENNA

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Abstract

A single chip V-Band pHEMT technology transmitter with wideband Direct BPSK modulation and on-chip dual band patch antenna is reported. The transmitter features, 10% bandwidth electronic tuning range, substantial power output, injection locking capability, low power consumption and good patch antenna radiation characteristics. As such it is well suited to wireless digital communications systems as well in radar and phased array applications.

i. Introduction

The monolithic integration of antennas with RF power sources is a key technique in realizing power efficient, transmit and receive circuit functions. In the mm-wave range, where interconnection losses with conventional techniques are higher, such integrated and unified active antenna design strategies become of prime importance.[1] On the other hand, for maintaining the functionality of digital transmitters, without implicating an increase in complexity, circuit size, and DC power consumption, direct RF carrier digital modulation techniques can be used [2]. In contrast with conventional heterodyne techniques, such direct RF carrier modulation schemes can readily provide small, high yield, reproducible, low cost and efficient mm-wave MMIC transmitter designs.

In this paper we present a V-band MMIC transmitter which comprises of a Voltage Controlled Oscillator (VCO) and a wideband balanced BPSK modulator, integrated with a multilayer patch antenna. The transmitter was fabricated on a AlGaAs/InGaAs pHEMT process with gate length of 0.25um. The BPSK transmitter features 10% electronic tuning range, wideband BPSK modulation, substantial RF power output, dual band operation and good radiation properties. It has a very low power consumption, and can be operated from a single 3V power supply. As such it is well suited for low power wireless digital applications in the indoor and local outdoor propagation environments. It is a potentially useful transmit element for intelligent phased array, radar, quasi-optical power combining, remote id, signal distribution and diversity system functions. The fabricated MMIC transmitter microphotograph is shown in Fig 1:.

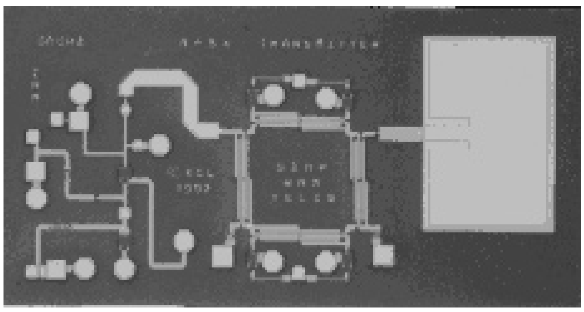

Fig 1:The MMIC Transmitter chip microphotograph

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ii.Transmitter Circuit Description

The respective circuit diagram of the transmitter is shown in Fig. 2.
The Voltage Controlled Oscillator (Fig 2a) comprises of a Common Source (CS) pHEMT transistor with positive inductive feedback at the source of the transistor. Tuning is achieved by employing a reverse biased pHEMT with drain and source connected together to act as a varactor diode. A matching network is included in the output of the oscillator for optimum power transfer.
A common technique for achieving BPSK modulation is to employ a reflection type topology using a Lange coupler with FETs as switches in the direct and coupled ports. When the switches are ON, the reflection coefficient is -1 (short circuit) while when they are OFF the reflection coefficient is + 1 (open circuit). The reflected signals add constructively at the output port only. However, at high frequencies the transistors' parasitics result in peaked amplitude and phase imbalances ie a non-ideal BPSK constellation. To eliminate such imbalances, a balanced modulator technique utilizing 2 reflection type BPSK modulators can be used. Each modulator is fed by complementary baseband signals S and $\overline{S}$ and is operating in a push-pull configuration (Fig 2b). This technique has been demonstrated using a balun in the input and an in phase combiner in the output [3],[4]. For MMIC implementation however baluns are difficult to implement and therefore Lange couplers in both input and output are used to induce the required 180^o phase shift [4]. The combined output is the sum of the 2 transmission coefficients of each branch. Due to the complementary nature of the baseband data, when the one branch is ON the other is OFF, or vice versa and therefore the response is totally symmetrical. Since Lange couplers are almost ideal this balanced BPSK modulator results in near perfect phase and amplitude balance.
The PHEMTS used are operated at zero drain bias (cold pHEMTs) and therefore consume minimal power.

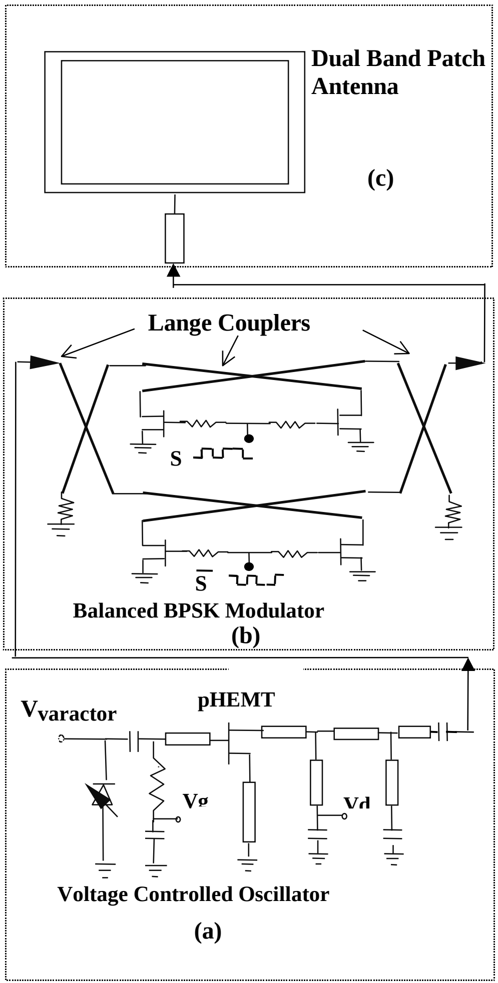

Fig 2: Circuit Diagram of BPSK transmitter

The multilayer patch antenna comprises of 2 half wavelength patches constructed using metals on different layers and operating at 2 different center frequencies. The lower patch employs an inset feed to reach an optimum impedance match to 50 Ohms while the upper one is electromagnetically coupled and excited by the lower patch [6]. The 2 metal layers are separated by a 1.4um thick polymide layer.

iii. Measured Results

The Transmitter, as well as its individual building blocks were fabricated using the GEC Marconi H40 0.25um pHEMT process on a 100um thin GaAs wafer. The size of the transmitter chip is 1.25x2.75 mm^2. The measurement setup comprised of a Cascade Microtech Probe Station equipped with 50-65 GHz Air Coplanar ACP65 probes and a scalar network analyzer utilizing WR15 waveguide directional couplers and the HP8562A spectrum analyzer with an external V band harmonic mixer.

The MMIC transmitter VCO was injection locked by injecting a low power locking signal through the drain bias line of the VCO's pHEMT. This was achieved either using the 3rd harmonic of a 17-20GHz injected signal, or by injecting a fundamental frequency locking signal. The power output of the VCO across its tuning range is shown in Fig 3. An average power output of approx 8dBm is achieved across the operating frequency range. A drain bias of V_d=3V is applied, drawing a current of 29.5mA.

Complementary pseudorandom sequence signals with a bit rate of 4Mbits/sec were injected at the S and $\overline{S}$ baseband ports. The respective BPSK spectrum at the first patch antenna resonance is presented in figure 4.

The dual band MMIC antenna return loss and gain are shown in figures 4 and 5 respectively while the E and H-plane radiation patterns at 1st and 2nd resonance are presented in Fig 6 and 7 respectively. The directivity of the patch antenna at 1st (f_1=57.3GHz) and 2nd resonance (f_2=59.4GHz) were numerically evaluated to be 6.7 and 8.3dB, while the antenna efficiencies were calculated to be 33% and 21% respectively. Ripple phenomena in the radiation pattern are mainly due to finite MMIC chip dimensions.

iv. Conclusions

A fully monolithic MMIC 60 GHz range transmitter with on chip direct BPSK modulator and dual band patch antenna has been fabricated for the first time. The MMIC transmitter chip seems to be a promising candidate for low cost, mass production, wireless mm-wave applications.

Acknowledgements

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References

1. J.A. Navarro,K. Chang,"Integrated Active Antennas and Spatial Power Combining",Wiley., 1996.
2. S.Kumar, "Directly modulated VSAT transmitters" , *Microwave Journal* , April 1990, pp.255-264.
3. Z. Adler and B. Smilowitz, "Octave band high precision balanced modulator", 1984 IEEE MTT-S Digest, pp.375-377.
4. S. R. Mazumder and R. C. Waterman, "A novel 6-18 GHz 180 degree bit phase shifter configuration aving very small amplitude and phase errors", 1994 IEEE MTT-S Digest, pp.83-86.
5. D. C. W. Lo, H. Wang, B. R. Allen, G. S. Dow, K. W. Chang, R. Lai, M. Biedenbender, S. Chen And D.Yang,: 'Novel Monolithic Multifunctional Balanced Switching Low-Noise Amplifiers', *IEEE Transactions on Microwave Theory and Techniques*, Vol. 42, No. 12, December 1994, pp.2629-2634.
6. D. Sanchez-Hernandez, Q.H.Wang, A.A.Rezazadeh, I.D.Robertson, "Millimeter-wave Dual Band Microstrip Patch Antennas using Multilayer GaAs Technology", IEEE Trans. Microwave Theory & Techniques, 1996, Vol 44, No9. pp1590-1593.

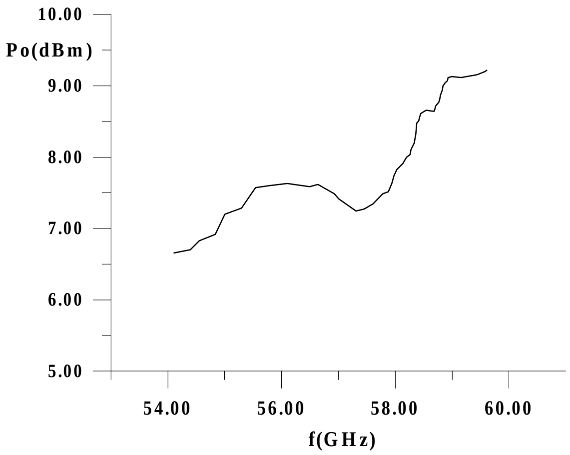

Fig 3: VCO power output versus frequency

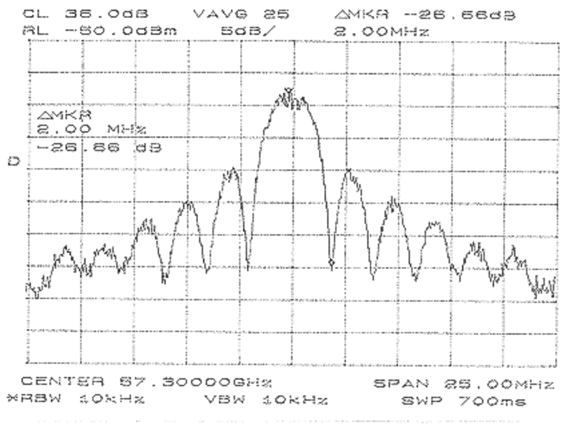

Fig 4: BPSK spectrum at 1st patch antenna resonance (modulation rate 4Mbits)

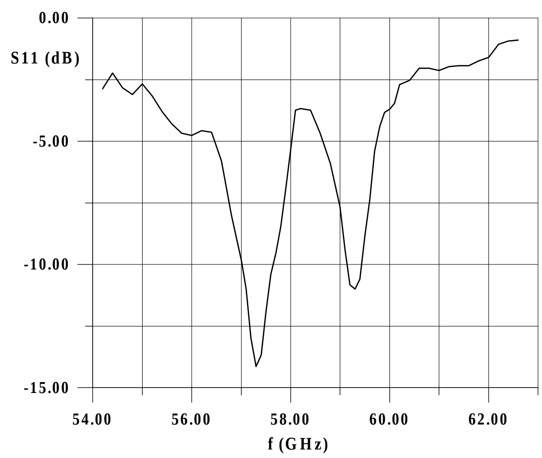

Fig 5: Dual Band Patch Antenna Return Loss

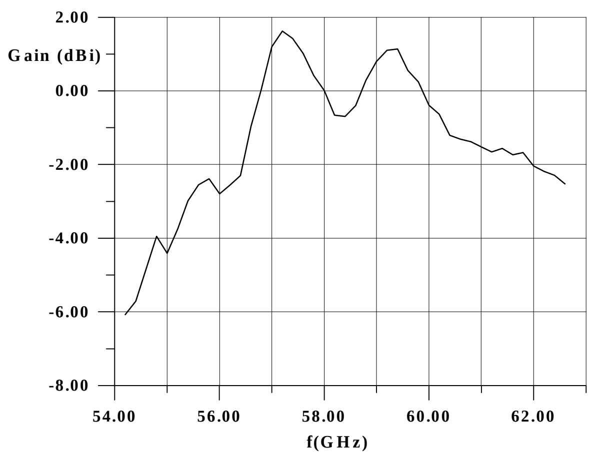

Fig 6:Patch Antenna Gain Vs frequency

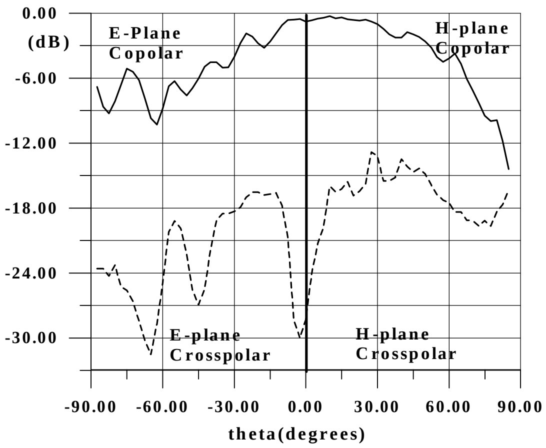

Fig 7: Radiation patterns at first resonance(f=57.3 GHz)

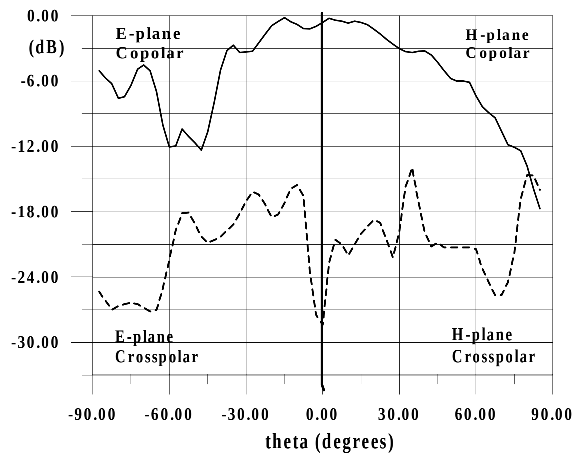

Fig 8: Radiation patterns at second resonance(f=59.3 GHz)