HBT Active Antenna as a Self Oscillating Doppler Sensor.

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Abstract:

This paper investigates the use of Heterojunction Bipolar Transistors as the working device in an active antenna for a self detection system. The devices used here are GaInP/GaAs HBT's from the GMMT F40 process. The design and performance of an active antenna based on this device is presented. A new large signal model is used to develop the active antenna described in this paper. The element oscillates at 11.40GHz and produces approximately 5mW of radiated power. A minimum detectable signal (MDS) of -99 dBm in a 10Hz bandwidth has been measured .

Introduction:

Self detecting Doppler radar systems have found applications in a range of areas including intruder alarms and collision avoidance systems.

The incorporation of two and three terminal devices with planar antennas has recently been reported by a few authors [2,3]. This paper demonstrates for the first time the use of a Heterojunction Bipolar Transistor as the oscillating element of an active antenna.

HBTs are currently used in many microwave and mmwave applications [4,5]. Oscillators are an important application for the HBT because of its high frequency and low phase noise capabilities, leading to the expectation of good self detection performance.

The high 1/f noise found in MESFETs and HEMTs limits the use of these devices. HBTs are thus promising devices for use in oscillator applications offering the low phase noise characteristics of bipolar transistors combined with the high frequency capability of GaAs devices. Many active antenna circuits have been developed which make use of the gain characteristics of active devices such as the GaAs MESFET [2], Gunn diode [3] and IMPATT diode [6]. Here the use of GaInP HBTs is introduce as the active element in active antennas.

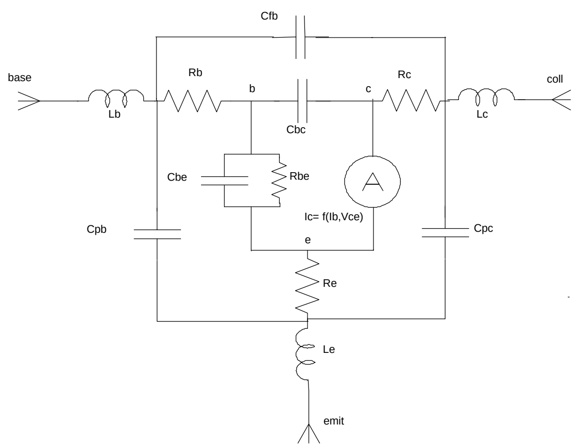

Figure 1: GaInP/GaAs HBT equivalent Circuit

HBT Device Model:

The device model used in the active antenna synthesis and analysis is described in reference [1] and shown in Figure 1.

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Here the intrinsic and extrinsic elements are obtained using a direct extraction and optomisation technique, with the non linear collector current being described using equation 1.

$$I_c \; k_1 \;/\; (1+\exp((-V_{ce}+k_2)*k_3))+0.2*\exp(-V_{ce}*k_4) \qquad \textbf{(1)}$$

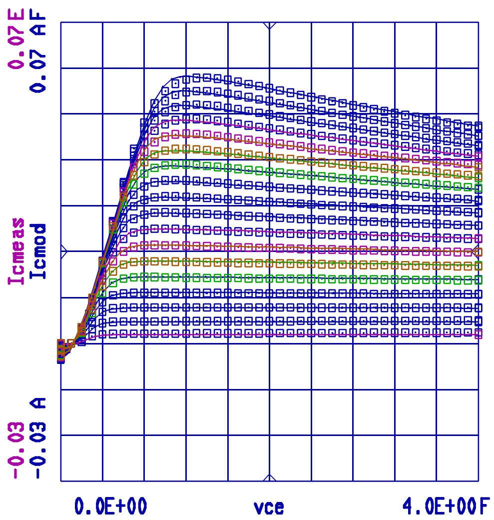


Figure 2(a): Measured (□) and Modelled (-) dc characteristics.

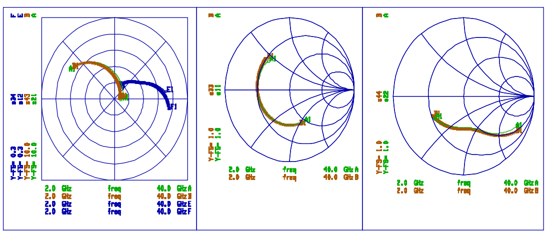
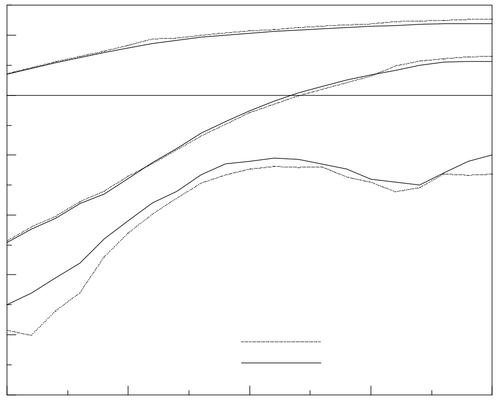


Figure 2(b): Measured (*) and Modelled (-) S-parameters.



where k_1, k_2, k_3 and k_4 are all simple functions of I_b fitted over the entire range. The full model has been successfully implemented on HPMDS and Figure 2 shows the measured and modelled dc (I_b= 0.2-3.6mA), small signal (0-40GHz) and large signal (f_0=2GHz into 50Ω) characteristics of the device.

Active Antenna Synthesis:

This model has been successfully used to design and analyse a series feedback oscillator operating into 50Ω at 11.25 GHz which was used as the oscillating element of the active antenna on Rogers[TM] 5880 duroid. The layout for the active antenna is shown in Figure 3 and the oscillator performance is shown in Figure 4. When attached to the patch antenna the active antenna element was pulled by 150MHz due to slight inaccuracies in circuit implementation.

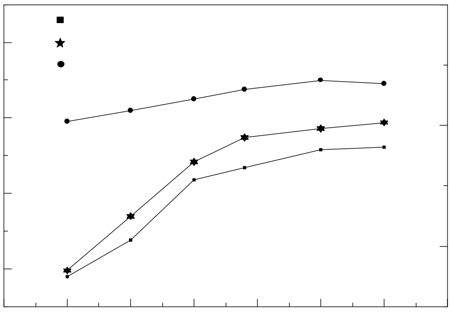


Figure 4: Variation of frequency and output power versus collector voltage for HBT oscillator.

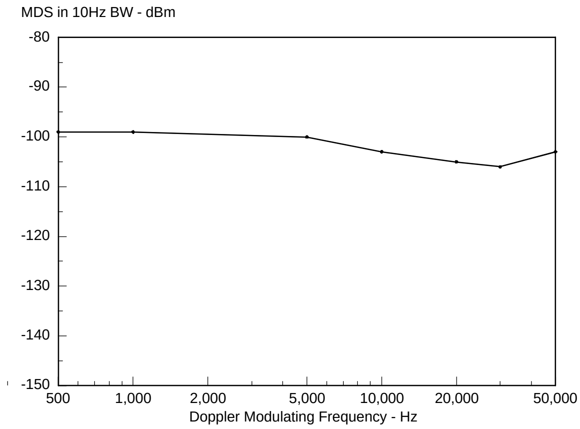


Figure 6: Measurement of MDS versur Doppler modulating frequency

Results of Self Detection Experiments:

Figure 5 shows a block diagram of the rf and low frequency circuit used for measuring the self detection performance of the HBT active antenna. In the rf circuit the received oscillator power is attenuated and fed through a PIN modulator. The signal is then square wave modulated and re transmitted through the receiving horn, returning to the active antenna. At the active antenna the return signal is mixed with the free running oscillator signal and the down converted signal

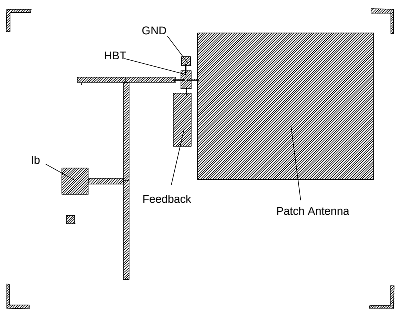


Figure 3: 11.40GHz HBT active antenna layout.

is picked up in the bias circuit and measured using a low frequency wave analyser.

The total signal path attenuation is calibrated so that the return signal power level can be computed from the output power of the oscillator. In the bias circuit the low frequency signal is obtained by using a coupling capacitor at the input of the wave analyser. Figure 6 shows the measured MDS of the HBT active antenna as a function of Doppler modulating frequency.

Conclusions:

It has been shown that, using simple design techniques and an accurate large signal model, as described here for a GaInP/GaAs HBT, then active microstrip antennas can be successfully fabricated using HBTs. When used in active microstrip antennas for self detection systems they show low power consumption and higher sensitivity when compared to MESFET and HEMT circuits [2].

Acknowledgement:

We wish to acknowledge GEC-Marconi Materials Technology Ltd., UK for providing the devices and device information and also support from Engineering and Physical Science Research Council (UK) under grant GR/H73967.

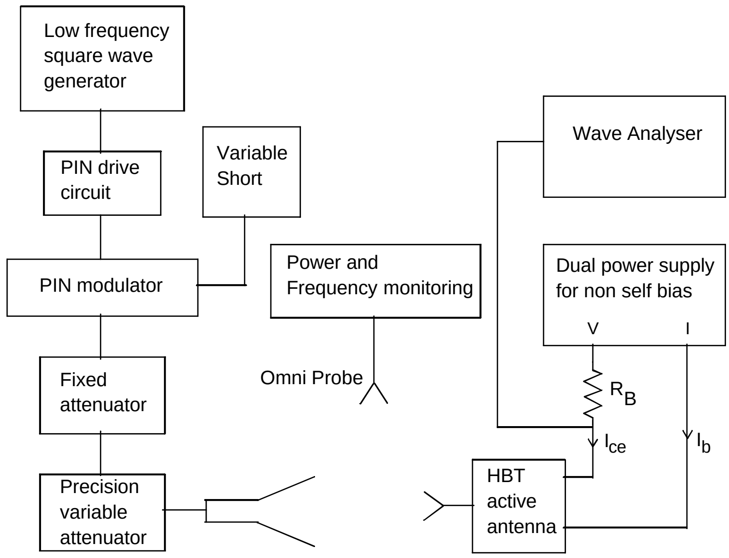


Figure 5: Measurement setup for self detection performance evaluation

References:

[1] Kelly M.J., Stewart J.A.C., Patterson A.D., "A GaInP/GaAs HBT Large Signal Model", EDMO Conference, Kings College London, pp 73-78, Nov. 1995.

[2] Sancheti S., "Active Microstrip Antenna Self Detecting Oscillator Characterisation", Ph.d thesis, Queens University Belfast 1995.

[3] Pollmann H, Engelmann R, Frey W, Bosch B.G, "Load Dependence of Gunn oscillator Performance", IEEE Trans. Microwave Theory and Techniques, Vol. MTT-18, Nov. 1970, pp. 817-827.

[4] Kroemer H., "Heterostructure Bipolar Transistors and Integrated Circuits", Proc. IEEE, Vol.70, pp. 13-25, 1982.

[5] Ali F., Gupta A., "HEMTs and HBTs, Devices, Fabrication and Circuits", Artech House, London, 1991.

[6] Gupta M.S., Lomax R.J., Haddad G.I., "Noise Consideration in Self Mixing IMPATT Diode Oscillators for Short Range Doppler Radar Approximations", IEEE Trans. Microwave Theory and Techniques, Vol. MTT-22, Jan. 1974, pp. 37-43.

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