Novel shifted-quadrant vector modulator.

The four-channel vector modulator [3][14] has a major advantage because the amplitude modulators can be simple variable gain amplifiers or variable attenuators, which have good linearity. However, it has disadvantages in terms of chip space, manufacturing cost and considerable inherent loss. Furthermore, it requires **four** baseband signals and for high-speed applications the cost of the required DACs is very significant. The two-channel (I-Q) modulator is conveniently compatible with digital modulation schemes, but the requirement for bi-phase amplitude controllers leads to the use of circuits such as mixers, which have poor linearity.

A novel solution is presented here, termed the **shifted-quadrant** vector modulator. Here, one pair of orthogonal channels is generated with variable gain amplifiers (or attenuators). This creates a single quadrant in the IQ plane, and a third **fixed** vector is used to shift this quadrant and centre it on the origin. Figure 2.16 shows the schematic of the vector modulator. The vector modulator is comprised of several RF components: For the Quadrature (Q)-channel (90 degrees) and the in-phase (I)-channel (0 degrees), two amplifiers with variable gain (VGA1 and VGA2) are used and one auxiliary amplifier is used to create the fixed quadrant-shifting vector (225 degrees). To construct a demonstrator using connectorised modulator components, the circuit also uses a mechanical phase shifter and variable attenuator for tuning the third vector.

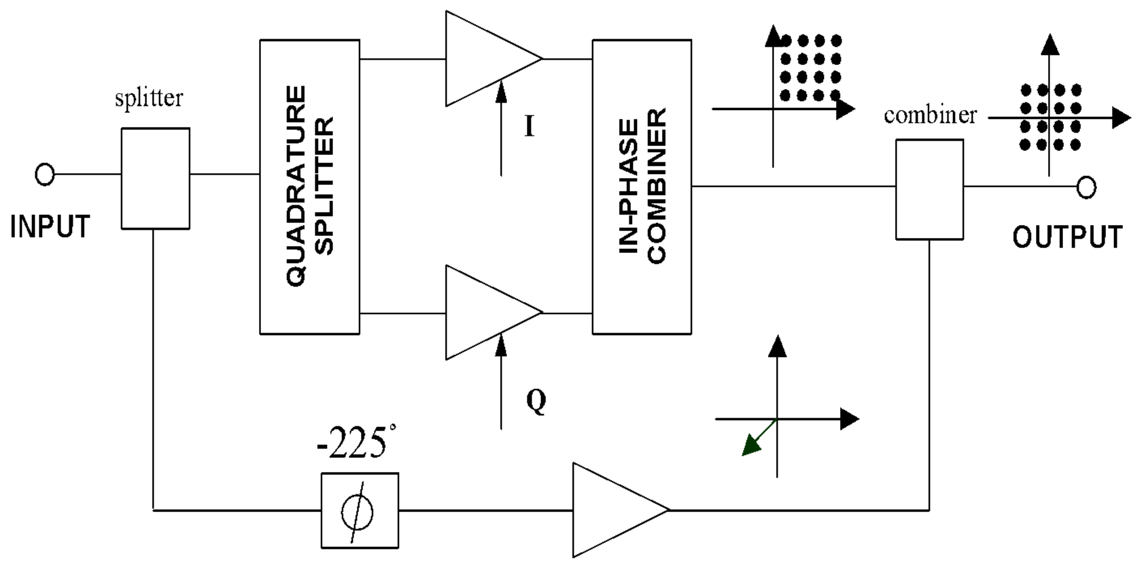

Figure 2.16: Schematic of the shifted-quadrant vector modulator.

2.3.2.1 Analysis:

Assuming the input signal can be expressed as:

V_{IN} =$A\cos\omega t$ (2.5)

And considering the input signal has a spectrum given by the following expression:

$$\vartheta_{IN}(\omega) = |\vartheta_{IN}(\omega)| \exp j\theta(\omega) \qquad (2.6)$$

The transmission coefficient of the phase shifter Φ needs to be considered. The compensation branch controls the centre position of the output amplitude and phase response and consists of an auxiliary amplifier, the phase shifter Φ and a variable attenuator. For convenience, the gain of this whole branch is defined as VGA3.

Each amplifier's transfer function is expressed as follows:

$$\Re_k(\omega) = \gamma_k(\omega) e^{-j\omega\tau_k} \qquad (2.7)$$

Where for the k^{th} amplifier, $\gamma_k(\omega)$ is the gain of a given k amplifier and τ_k represents the group delay.

Assuming I and Q are set to be in the range 0 to 1, the output signal for an input signal V_{IN} =$A\cos\omega t$ can be expressed as: -

$$V_{out} = A\alpha\sqrt{\frac{2}{5}}\, I\cos(\omega t) + jA\alpha\sqrt{\frac{2}{5}}\, Q\sin(\omega t) + \frac{A\alpha}{\sqrt{5}}\cos(\omega t - \frac{5}{4}\pi) + j\frac{A\alpha}{\sqrt{5}}\sin(\omega t - \frac{5}{4}\pi) \qquad (2.8)$$

α represents the total splitting and combining losses: further work is required to investigate the optimum topology of this technique in order to minimise combining loss and maximise the output 3rd order intercept. The fixed vector is 3dB lower than each I/Q vector, and this is simple to implement with a variety of coupler and power splitter combinations. Recently, techniques for realising a 45degree power divider have been demonstrated, for application in harmonic mixing, and this can be applied to create the 225 degree vector.

2.3.2.2 Measured Results:

The modulator was set up using two MiniCircuits variable gain amplifiers, with appropriate power splitter/combiners. The fixed branch was implemented with a mechanical phase shifter, variable attenuator and amplifier. Figure 2.17 shows the measured transmission response of the vector modulator at 2GHz for a selection of bias points, and confirms that a squared constellation centred on the origin is achieved after tuning. Figure 2.18 shows the intercept diagram obtained by injecting a two-tone RF signal into the modulator. The 3rd-order output intercept point of 25dBm is very much higher than that of most vector modulators using mixers.

It has been shown that the four-channel vector modulator can be reduced to two channels using the "shifted-quadrant" approach. This compromise solution needs only simple variable attenuators or amplifiers and has only two variable channels. It is expected that this could be of particular interest in RFICs, which normally use the Gilbert cell modulator, which has very limited power handling.

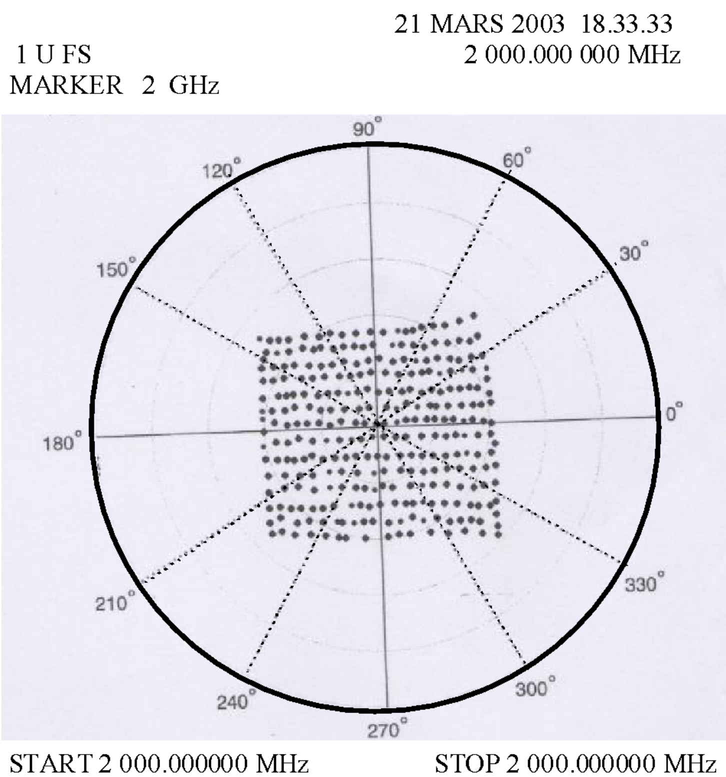

Figure 2.17: Transmission response of the shifted-quadrant vector modulator at 2 GHz for various I/Q bias points

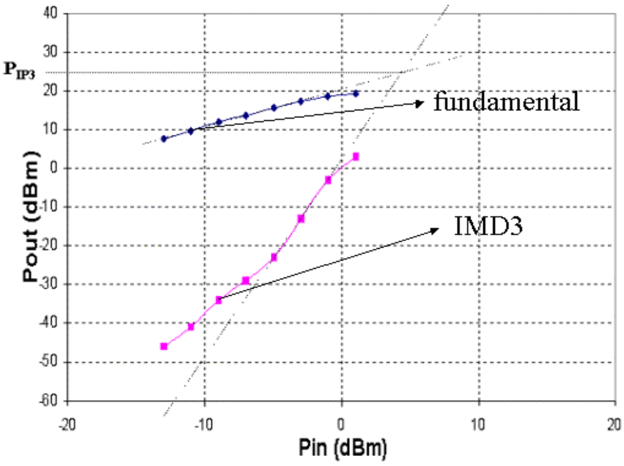

Figure 2.18: Measured intercept diagram for the vector modulator at 2GHz

2.4 Summary

This chapter has explored different ways of designing microwave vector modulators. A brief discussion of the microwave vector modulator for direct carrier modulation in communication transceiver has been given. Technically, the I-Q type vector modulator with reflection topology attenuators (RTAs) has great advantages compared with phase-shift/attenuator (PSA) type vector modulator.

The result of an analysis of the effect of cold-FET parasitic elements on the bi-phase modulator and vector modulator has been described. A new simple technique to correct the phase distortion and extend the dynamic range of attenuation has been developed. The asymmetry of modulator insertion loss between the two bias extremes, $V_{gs} = 0$ and near the pinch-off, is also corrected by simply adding a shunt resistor. Simulation and experimental results demonstrate the effectiveness of the proposed technique.

A new "quadrant-shifted" vector modulator has been introduced for the first time and published in the IEE Electronics Letters (Volume 39 Number 14 - July 2003). It is a compromise between the four and two-channel vector modulators: it requires only two baseband signals (I and Q) but does not need bi-phase amplitude modulators, so it has great potential for further development.