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COMBINING PREFILTERING AND PREDISTORTION IN A HIGH POWER DIRECT PSK MODULATOR

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Abstract:

Predistortion linearizes a high power direct PSK modulator. A digital method of combining prefiltering and predistortion for the modulator is proposed. From the spectra as well as the demodulated eye diagram results it is observed that in addition to spreading of the filtered baseband spectrum, the modulator nonlinearities also introduce inband noise components. This technique of implementing the baseband signal processing paves the way for combining the microwave and baseband signal processing in a single MMIC chip.

INTRODUCTION

Recently there has been a surge in the design of complex monolithic integrated circuits with more than one function on a single chip. Combined microwave/digital functions have been demonstrated recently [1]. These monolithic integrated circuits have advantages of light weight, small size, increased reliability and low cost in large volume production. One application which would benefit from monolithic design is a transmitter for *Very Small Aperture Terminals*.

The transmitter in a VSAT typically uses PSK modulation at a low data rate and a power output of 1-2 W. Microwave bandpass filtering is not practical in a VSAT transmitter because of the need for very high Q narrow band bandpass filter. A generally accepted alternative is lowpass prefiltering of the digital data. A practical modulator does not preserve the filtered baseband spectrum due to the nonlinearities. Predistortion of the filtered data can be used to counteract the modulator nonlinearities [2]. In their paper [illegible] et al have reported the problem of spectrum sidelobe spreading. A more thorough investigation shows that there is a noticeable distortion in the main lobe of the PSK spectrum as confirmed by the demodulated eye diagram results.

This paper gives a design outline of the microwave circuit and a versatile digital memory based method of combining prefiltering and predistortion. All the components used in the design can be realized on the same substrate and hence the microwave and baseband processing circuits can be integrated into a single MMIC chip.

MICROWAVE CIRCUIT DESIGN

The structure of the VSAT BPSK transmitter is shown in Fig. 1. It consists of a baseband signal processing block, microwave circuit, carrier oscillator, saturated power amplifier and a dish antenna. This design is more compact and cost effective than the conventional chain of IF modulation, bandpass filtering, upconversion and linear power amplification.

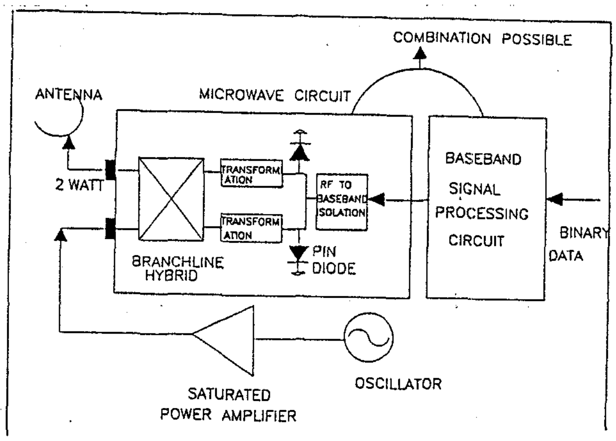

Fig. 1. Schematic diagram of the VSAT transmitter.

The microwave circuit consists of a branchline hybrid, transformation networks, PIN diodes and RF to baseband isolation on a microstrip substrate. The design is done to meet the specification of 2 W power output, 180° plus or minus 2° phase shift between the binary phasors and amplitude imbalance of 0.2 dB over 5.925-6.425 GHz. Eventhough present North American VSAT systems use Ku band with the transmit frequency of 14-14.5 GHz, the 6 GHz band of operation was selected to limit the practical problems to those involving the modulator only. By suitablescaling of microstrip substrate parameters it is easy to extend the same design to Ku band. The ideal 180° performance obtained using (Hyperbolic Midpoint Matching) [3] is valid only at a single frequency. Computer Aided Optimization with Touchstone[1] is used to exactly synthesize a broadband transformation network, which yields the required performance across the band.

LINEARIZATION

Fig. 2 shows a plot of measured reflection coefficient of the matched PIN diodes versus the output voltage V_p of the baseband circuit. The dynamic reflection coefficient is measured by giving a sweep voltage ranging from -1.5 V to + 1.5 V and measuring the reflection coefficient using the network analyzer. It is seen that Γ

1 Touchstone is the trade mark of EEsof Inc.

is a nonlinear function of V_p. Filtered PSK is obtained if the modulator output can be written as.

$$\Gamma \cos\omega_c t = K V_p + K_1 \ . \qquad (1)$$

A filter output of 1.0 V has to be distorted to 0.7 V as illustrated. Thus the predistorter characteristic can be obtained graphically.

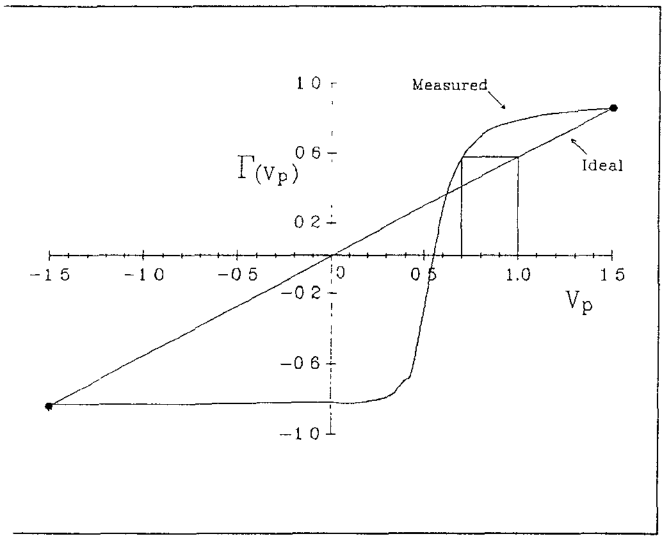

Fig. 2. Modulator reflection characteristics.

FILTER AND DISTORTER

A raised cosine filter with roll off factor $\beta = 0.3$ is chosen for implementation. Let h(t) denote the impulse response of the filter. The output of the filter for an impulse train of -1 or +1 is:

$$y(t) = \sum_k a_k h(t + k T_b) \qquad (2)$$

The filter output is scaled by a factor of 1.5 to conform to the range of the voltage V_p. The symbol a_k denotes the data (-1 or +1) in the k^{th} bit period kT_b. From the impulse response plot [4], it is seen that ISI (Inter-Symbol Interference) can be limited to (2M) 6 bits. For our implementation, (L) 16 samples of filter output per bit were chosen i.e. sampling interval $\tau_c = T_b/16$. The j^{th} sample in the n^{th} bit period is given by:

$$y(j\tau_c + n T_b) = \sum_{k=-3}^{3} a_{-k+n} h(j\tau_c + k T_b) \ . \quad 1 \le j \le 16 \qquad (3)$$

For experimental purposes a HP 9000 computer was used to generate the digital samples. The distortion described earlier is applied to each sample to get the output sample value. The samples were converted to analog values by D/A, smoothed by an opamp low pass filter and fed to the driver. The driver voltage was applied to the PIN diodes.

The proposed circuit realization [5] is shown in Fig. 3. The filtered and distortedsample values for a particular bit stream (present and ISI bits) can be stored in a PROM The sample values stored in the PROM for a particular bit combination are addressed by a 7 (2M+1) bit data shift register that takes care of the ISI, and each sample in a bit interval is selected by a m = 4 bit synchronous counter whose clock frequency is 16 times the data clock frequency. Assuming 8 bits are used to represent a sample value, this design requires a $2^7 \times 16 = 2$ Kbyte PROM. This baseband implementation is very flexible. The bit rate can be changed by changing the clock frequency. The filter and predistorter characteristics can be changed by changing the contents in the PROM.

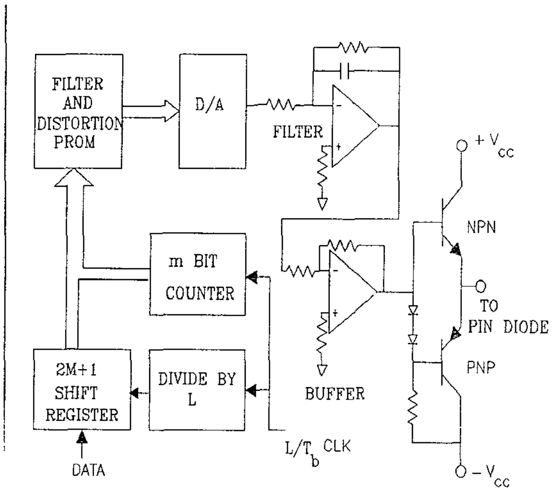

Fig 3. Circuit realization of filter-distorter.

RESULTS

Fig. 4 shows the output BPSK spectrum before linearization. As seen in Fig 5the sidelobes are attenuated appreciably after linearization. The eye diagrams of the baseband data and demodulated data before and after linearization are are shown in Fig. 6 and Fig. 7 respectively. The demodulated eye diagram (in the lower trace of Fig. 6) does not resemble the original baseband raised cosine filtered eye. The distortion in the detected eye represents the inband noise introduced by the modulator nonlinearities. After applying predistortion (upper trace of Fig. 7), the demodulated eye (lower trace of Fig. 7) resembles the original filtered baseband eye (upper trace of Fig. 6). Comparison of the BPSK spectrum before and after linearization also reveals that the main lobe has regained its shape. This is accentuated by the demodulated eye diagrams. The introduction of inband noise components by the modulator nonlinearities has not been reported in the literature.

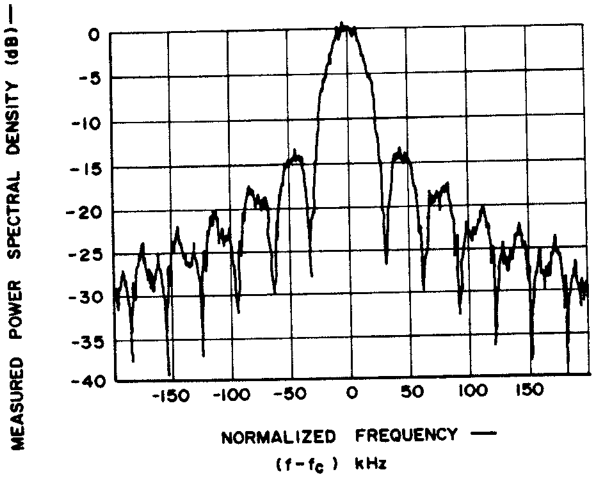

Fig. 4. Modulator output spectrum before linearization.($f_c = 6$ GHz)

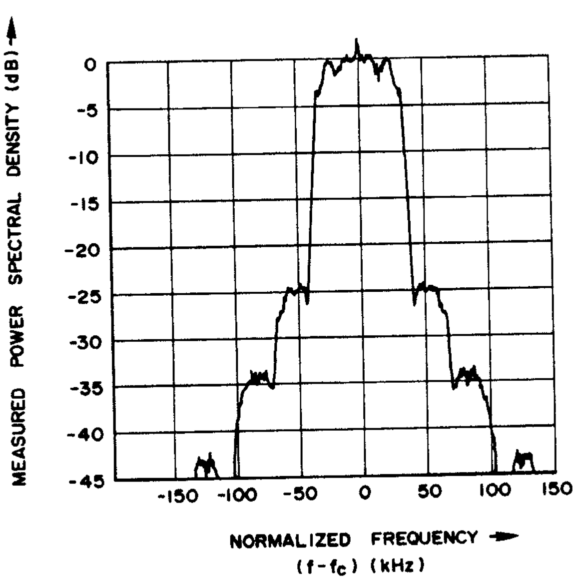

Fig. 5. Modulator output spectrum after linearization.($f_c = 6$ GHz)

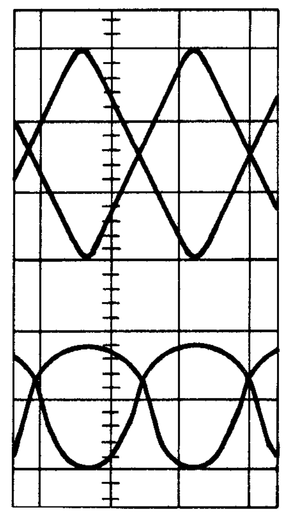

Fig. 6. Upper Trace: Raised cosine filtered eye. Lower Trace: Demodulated Eye before linearization.

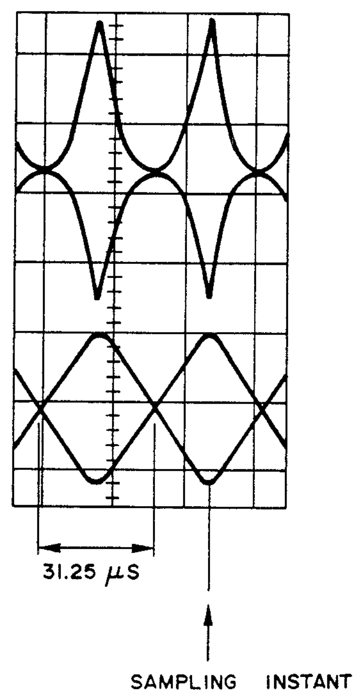

Fig. 7. Upper Trace: Raised cosine filtered-distorted eye. Lower Trace: Demodulated Eye after linearization.

CONCLUSION

Microwave circuit represented by the branchline hybrid, transformation network, PIN diodes and baseband-RF isolation can be integrated with the compact baseband digital memory circuit consisting of shift register, PROM, smoothing filter and driver using the state of art MMIC techniques. The technique described in this paper can be used in the design of transmission type PSK and FSK modulators.

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