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TEMPERATURE CONTROLLED PREDISTORTION CIRCUITS FOR 64 QAM MICROWAVE POWER AMPLIFIERS

M. Nannicini, P. Magni, F. Oggionni

Microwave Communication Division
Telettra S.p.A. - Vimercate (Mi)
Italy

Abstract

This report deals with the problem of non-linearity characteristics in microwave power amplifiers for digital radio link systems with multi-level modulation (ex. 64 QAM); and in particular with reference to their degradations vs temperature variations.
Moreover various possible methods of compensation are taken into account.
After a brief examination of the not temperature controlled predistortion method operating at intermediate frequency, solutions are suggested to keep the non-linearity characteristics independent from thermal conditions.
By presenting the experimental results and the comparative considerations, the use of the "feedback controlled predistorter" and the "predictive method" is analysed.

Introduction

The evaluation of the non-linearity characteristic of the GaAs FET power amplifier and the analysis of methods used to optimize performances are of great importance in digital transmission systems over an RF carrier with multi-level modulation (64 QAM).
The multi-level systems are sensitive to amplitude (AM/AM) and phase (AM/PM) distortions, which are typical in microwave power amplifiers (Ref. 1). In particular depending on temperature, the two types of distortion increase, the AM/PM distortion being more accentuated (see fig. 1).
In multi-level systems distortions are put in evidence by a bit error probability (BER) increase. The techniques used to improve the microwave amplifiers performances are widely described in literature, some references of which are listed below: - through prerotation and derotation it is possible to act directly on the modem (Refs. 2-3)
- predistortion - because of its scheme simplicity and circuitry it is widely used in digital transmission systems with multi-level modulation (Refs. 4-5)
The non-linearity system minimizes the third order distortions generated by the microwave amplifier. It also generates higher order intermodulation products at a -20 dB level, with respect to the preceeding ones.
In this way the IM_5 distortions of the predistorter + amplifier assembly are kept under control.
This study deals with the "techniques" used to contain the non-linearity degradation caused by thermal variations.
In microwave systems with GaAs FETs, the non-linearity vs temperature variations depend on the compression gain shifting and on the relative gains of the devices.
Stability of the linear gain versus temperature and versus device characteristics spreading is ensured by an ALC loop. The output detector is optimized to give a voltage proportional to the mean value of the RF signal, in order to avoid that ALC operating depends on the amplitude modulation index of the RF signal (Ref. 1).

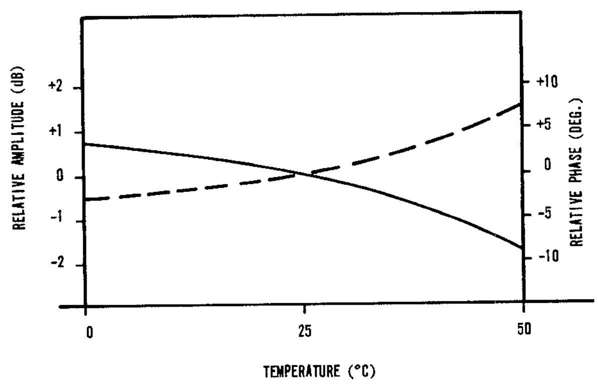

Fig.1 - Distortion increase AM/AM and AM/PM vs temperature

Generally predistorters used in digital radio links are provided with IF four terminal networks able to produce distortions complementary to the microwave amplifier without any feedback circuit.

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A non-linearity distortion decrease may be reached by assigning a consistent back-off to the amplifier thus reducing the amplifier efficiency and introducing considerable problems of heat dissipation.
The administration tenders require that the transmission systems guarantee for a normal working operation within a temperature range from approx 0° to 50°C. Hence it is necessary to keep the non-linearity characteristic constant, particularly in 64 QAM systems requiring very high non-linearity performances.
Two systems have been experimented; one provided with feedback and the other one, called predictive method, combined with GaAs FET microwave power amplifiers so as to maintain vs temperature the improvements introduced by the predistorter.
Fig. 2 shows the Bit Error Rate trend vs the received field both for 16 and 64 QAM systems with and without predistorter.

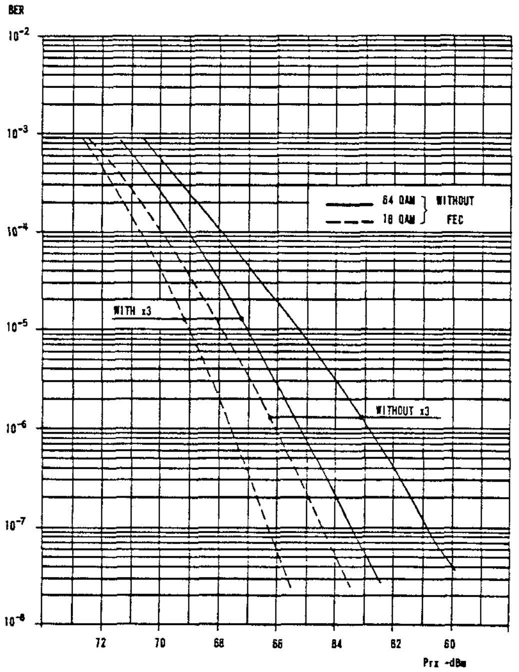

Fig.2

Feedback controlled predistorter

Fig. 3 shows the system block diagram. The digital signal at the microwave power amplifier output is reconverted into IF and summed up in phase opposition to the main signal.
The difference between IF1 and IF2 produces error signal "e" and a residual of the main signal decreased by 30 dB approx.
The distortions obtained from the two filters placed in the centre of the sidebands (f- and f+ frequency) of the 64 QAM spectrum are amplified and detected to obtain the information relative to distortions (Fig. 4).

The delay line on the IF1 path compensates for the electric length of the microwave amplifier and of the up and down converter chain. The endless shifter instead places the two signals in perfect phase opposition thus rigorously compensating for the phase error caused by the electric path difference between the Local Oscillator
and the up and down converter.

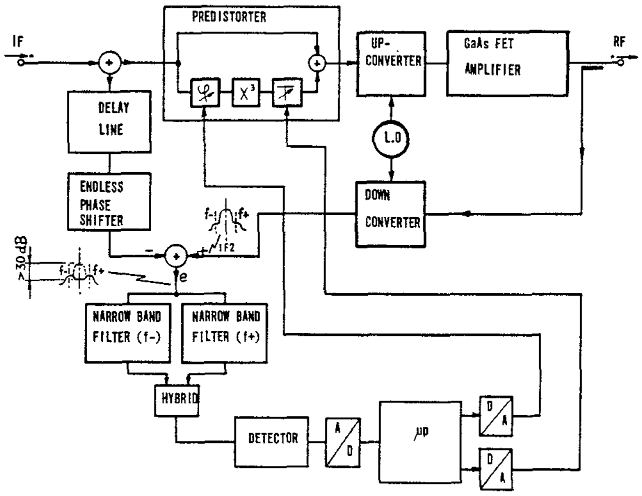

Fig.3

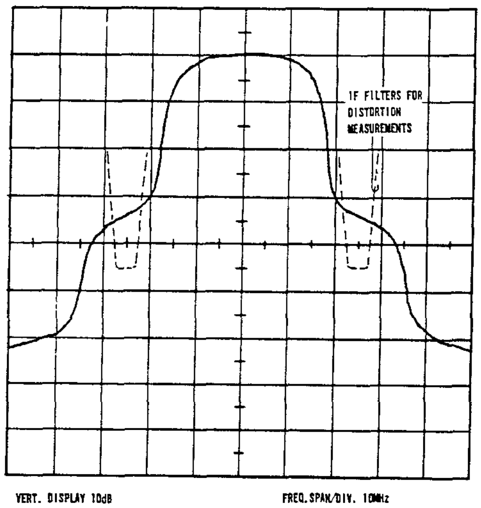

Fig.4 - Down converter output IF spectrum (64QAM) and trend of filters for distortion measurements

The non-linearity characteristics improvement is reached by acting on the predistorter,
by means of the phase and amplitude control.
The flow chart of Fig. 5 shows the algorithm followed by the check system for improvement.
The detected signal containing the distortion information is digitalized by means of an 8 bit A/D converter.
Upon an increase of error signal "e", the logic performs an optimization, so that the relative

minimum of "e" itself is reached.
The hardware uses an 8 bit microcomputer of the 8048 family able to directly control the A/D and D/A converter.
The picture of Fig. 6 shows the system complete with an RF GaAs FET amplifier predistorter, IF module and the check microprocessor.

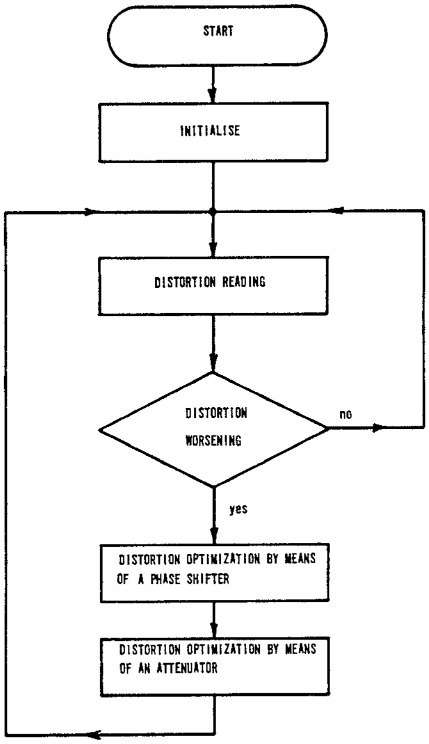

Fig.5 - Check logic to microprocessor flow chart

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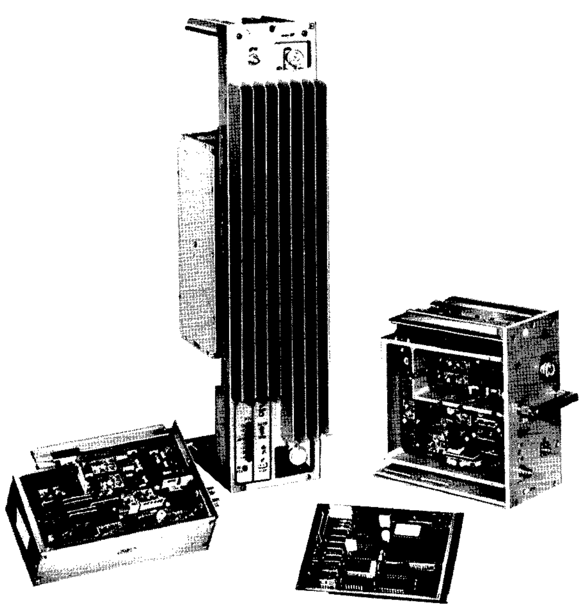

Fig.6

Predictive method

A functional diagram of the digital predictive method is shown in Fig. 7.
Manufacturers of devices, who are now sensitive towards modulation problems, have started the production of GaAs FETs provided with particular physical characteristics (see better GATE profiles and the optimization of the "delta shape" carriers profile) aiming to improve the devices linearity.
A further improvement is obtained by selecting the characteristics of the devices used in microwave power amplifiers which reduces the average loss of the characteristics detected on a certain number of amplifiers within an ever diminishing range; moreover, a suitable aging of the amplifier in the factory keeps them constant in time.
This makes the use of the predictive system more efficient. For a correct temperature measurement the temperature sensor is placed near the final stage of the GaAs FET device.
The digital data of the AM/AM and AM/PM characteristics trend are memorized in EPROM.
The amplifier temperature is read by the check logic and, on the basis of the memorized characteristics, it supplies the phase shifter and the variable attenuator with the driving signals.

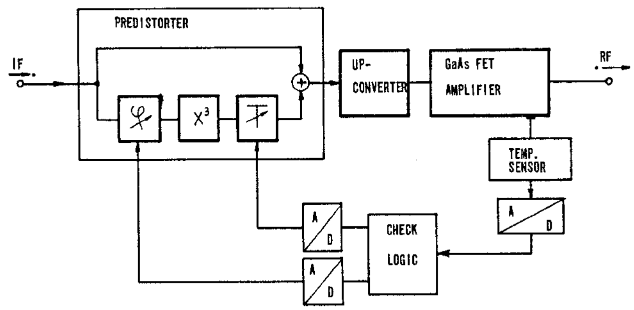

Fig.7

Experimental results

In the laboratory, by using the above mentioned two temperature controlled predistortion techniques some experimental tests have been carried out on 64 QAM systems at 90 Mbit.sec in the 4 GHz range and at 135 Mbit/sec in the 4 GHz and 6 GHz ranges.
Temperature has caused variations of 5 dB approx on the "intermodulation sidebands" of the 64 QAM spectrum, if temperature control loop is not used. With the feedback controlled predistorter these variations are within 1 dB approx, while with the predictive method they are within 2 dB approx, in the 0° to 50°C temperature range (Fig. 8).

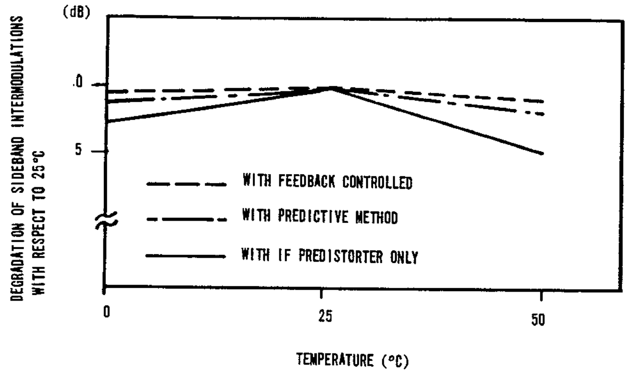

Fig.8 - Comparison between the intermodulation sidebands vs temperature for the described methods

Fig. 9 shows the confrontation of the intermodulation ratio trend (IM_3) vs the amplifier back-off with 16 and 64 QAM systems.
With an equal nominal output power and with respect to the 16 QAM systems, the 64 QAM systems require a higher intermodulation ratio (IM_3) which may be obtained by means of an 8W "1 dB compression point" instead of a 5W "1 dB compression point", as in the 16 QAM case.

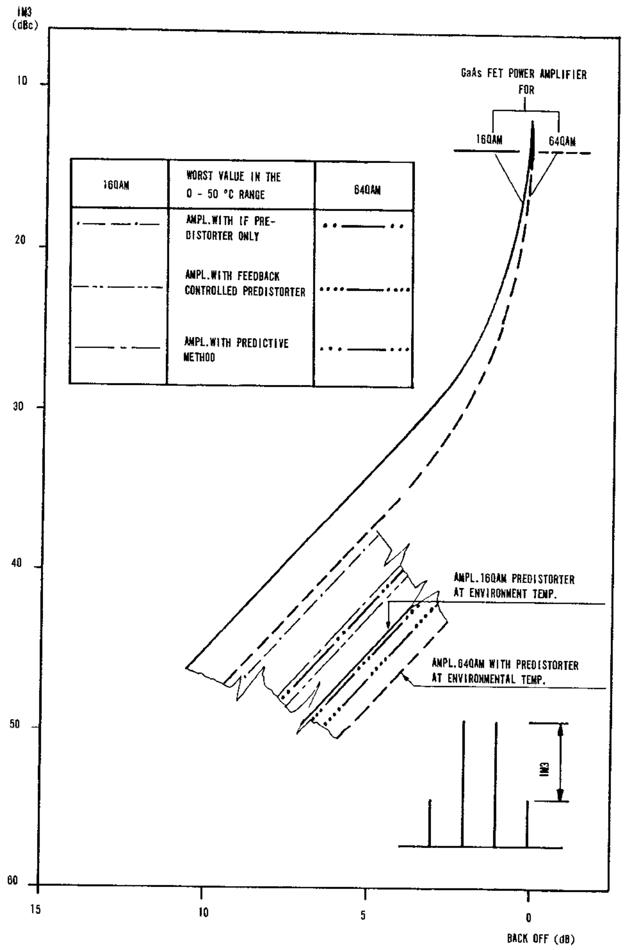

Fig.9

The curves with and without predistorter have been drawn; in presence of a predistorter
the values the system may guarantee are in the 0° to 50°C range.

Conclusions

The feedback controlled predistorter permits to optimize the results but a considerable circuitry is needed. The predictive method instead permits to maintain the degradations of distortions vs temperature within an acceptable range through a simple circuit solution.

Aknowledgments

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