Pre-distortion simplifies mobile data integration

Interfaces between data modems and existing voice-grade radios are more efficient with pre-distortion signal processing. Thus, a larger number of radio models can be used for 4,800bps and 9,600bps operations.

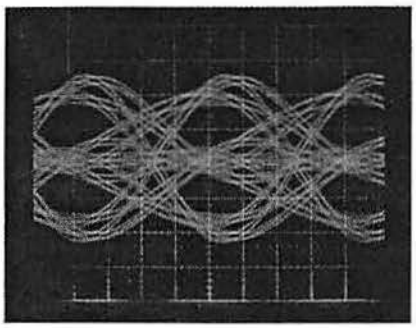

Photo 1. An eye pattern distorted by the Mitrek circuitry.

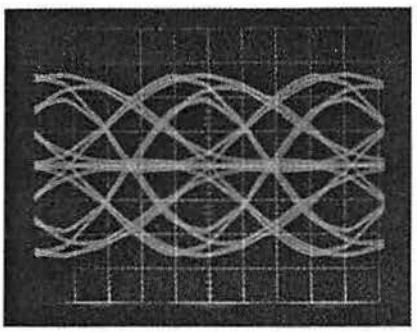

Photo 2. An eye pattern of a pre-distorted signal.

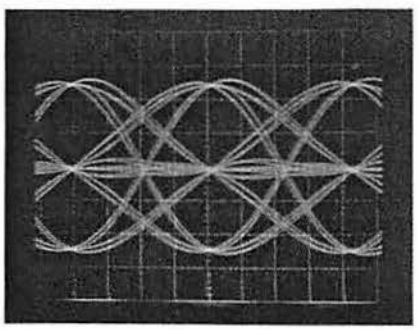

Photo 3. An eye pattern of a pre-distorted signal after it passes through the Mitrek circuitry. Note how the resulting signal is symmetrical and how it converges to three distinct points.

By Barry Dorr

Pre-distortion is a signal processing technique that yields more efficient interfaces between data modems and existing voice-grade radios.

A result of this technology is that a greater number of radio models can be used for 4,800bps and 9,600bps operation, and fewer radio modifications are required. Thus, users can send high-speed data while retaining their investment in mobile radio and base station equipment.

How pre-distortion works

As a general rule, higher data rates occupy more audio bandwidth than lower data rates, requiring radios with a wider audio bandwidth. Audio group delay must remain relatively flat over this bandwidth. At 4,800bps data rates, voice-grade radios normally do not meet the requirements for bandwidth and group delay.

System integrators traditionally solve this problem by modifying the radio so that the transmitted signal is sent directly to the voltage-controlled oscillator (VCO) input. When this method is not possible because of low impedance, low distortion or the lack of a good audio summing point, the radio model is rejected for use at high baud rates.

The solution is to select a convenient transmit interface point and digitally pre-distort the signal in the modem.

As an example, the Motorola Mitrek radio's VCO input has a 100Ω input impedance, which is too low for a low-power data modem. The radio has an interface point that has high impedance and that allows summing of the voice signal, but it does not provide a satisfactory interface at 4,800bps.

The audio magnitude and group delay of the transmit circuitry between the selected interface point and the VCO input are shown in Figure 1 on page 37. As with most radios, the Mitrek's high-frequency audio response is limited to reduce noise. Although it is not shown by the graph, the low end of the radio's audio frequency response is limited by capacitive coupling in the audio path.

As a general rule, higher data rates occupy more audio bandwidth than lower data rates, requiring radios with a wider audio bandwidth.

The audio spectrum of the 4,800bps Nyquist-filtered bipolar (NFB) signal is shown in Figure 2 on page 37. Because the signal has no low-frequency component, the low-frequency limitation due to capacitive coupling is not a problem.

The high-frequency limitation, how-

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Definitions:

Digital signal processing (DSP) — The processing of analog signal using digital techniques.

Eye pattern — The waveform pattern of a modulated digital signal as seen on an oscilloscope. The vertical display is driven by the information-carrying waveform, synchronized by the system clock.

Group delay — A type of distortion caused by different frequencies that take different amounts of time to pass through a filter.

Nyquist-filtered bipolar (NFB) — A signaling technique commonly used at 4,800bps. The most salient characteristic of this scheme is that it has no dc component. Therefore, an NFB signal passes through capacitively coupled channels.

Transfer function — A function that describes the magnitude and group delay response for a linear filter.

Voltage-controlled oscillator (VCO) — The fundamental element of an FM transmitter. The VCO converts audio-level signals into deviations of an RF carrier's frequency.

ever, causes distortion. Photo 1 on page 34 is an eye pattern distorted by the Mitrek circuitry. The distortion it represents is unacceptable.

The signal will be passed by the Mitrek if it is pre-distorted so that the transmit circuitry *actually is required*

...the transmit circuitry actually is required for a clean signal.

for a clean signal. This is done as follows:

If the transfer function of the transmit circuitry is Hd(s) and the desired transfer function of the modem *and* processing circuitry is Hn(s), then the digital filter required for the Mitrek can be expressed as Hn(s)/Hd(s).

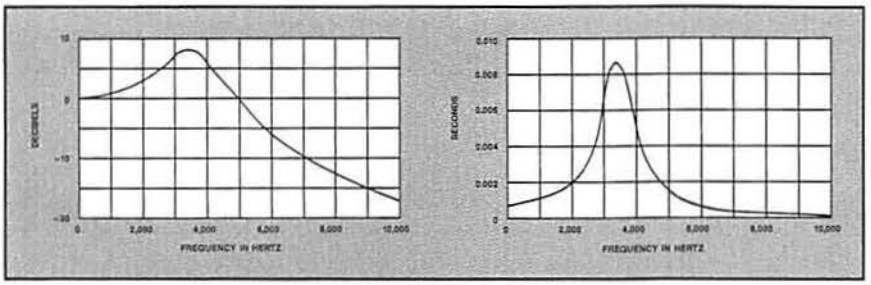

Figure 1. The audio magnitude and group delay of the transmit circuitry between the selected interface point and the VCO input.

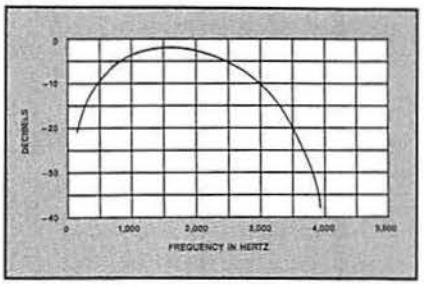

Figure 2. Audio spectrum of the 4,800bps Nyquist-filtered bipolar (NFB) signal.

With this filter, the cascaded response is Hn(s)*Hd(s)/Hd(s) = Hn(s).

The pre-distorted eye pattern is shown in Photo 2 on page 34. When this signal is passed through the Mitrek transmit circuitry, the result is as shown in Photo 3 on page 34. Note how the resulting signal is symmetrical and how it converges to three distinct points.

In the modem, digital transmit filters for many radio types are stored in memory.

Implementing pre-distortion

In the modem, digital transmit filters for many radio types are stored in memory. During initial setup, a filter is selected that is matched to a factory-recommended transmit interface point.

Pre-distortion is a signal processing technique that allows high-speed data to be sent using voice-grade radio equipment—one of many uses for digital signal processing in mobile radio communications.

Using digital signal processing to correct for the imperfections and differences in existing radio equipment allows users to send high-speed data and retain their investment in mobile radio and base station equipment.