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A HIGH-SPEED RF DATA TRANSMITTER FOR THE FERMILAB BOOSTER BEAM DAMPING SYSTEM

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Summary

This paper describes the design and realization of an RF transmitter system capable of driving very fast modulation envelopes (12 ns - 20 ns) representative of analog signals through long coaxial cables. The transmitter employs two amplitude-modulated carriers to transmit the amplitude and the polarity of the input drive signal simultaneously, via frequency-division multiplexing over an 800 MHz spectrum in the VHF and UHF bands.

Refer to separate papers[1] for information regarding the damper system and its other specific components.

Introduction

In order to implement the active beam damping system for the Fermilab booster synchrotron, a method of transmitting beam position signals through the system cable delay line was developed. These position signals consist essentially of a random series of bipolar DC levels from 12 to 20 ns in duration, ranging from -2.5 V to +2.5 V, with transition times of about 3 ns between each level.

Direct transmission of beam position information was rejected mainly because the fast transition edges of the signal would be badly distorted by the inherent losses of the long coaxial cable used to introduce a one-turn booster time-of-flight delay into the feedback loop of the damper. Therefore, an RF transmission scheme was utilized to avoid the principal distortion effects of this cable.

Transmitter Realization

Overall System

Figure 1 is a block diagram of the data transmitter. Double-sideband amplitude modulation was chosen for its efficient use of bandwidth and its realative ease of implementation and detection at high speeds. A dual-channel frequency-division multiplexed system was developed to transmit the amplitude and the polarity of the beam position signal simultaneously on separate carrier frequencies.

High-frequency construction techniques were necessary throughout the transmitter, making the minimization of cabling and connectors essential for preserving intercircuit matching. The entire unit is housed in a 4-wide NIM module.

Amplitude Channel

For good fidelity through the transmission-reception system, an upper limit of 4 ns was placed on the rise and fall times for the amplitude channel modulation envelope. Since:[2]

$$t_r = \pi/\omega_o \qquad (1)$$

where:

t_r = envelope risetime

ω_o = single-sided bandwidth from carrier frequency.

With the risetime requirement of 4 ns, the minimum single-sided bandwidth f_o is then:

$$f_o = \frac{\omega_o}{2\pi} = \frac{1}{2t_r} = 125 \text{ MHz} \qquad (2)$$

Allowing an approximate margin of 40%, a design single-sided bandwidth of 175 MHz was used, with a carrier frequency of 250 MHz.

Modulation is accomplished with a high level (+23 dbm) double-balanced mixer. The amplitude channel is band-limited by means of an eigth-order Tchebychev low pass filter. This filter has equal-amplitude passband ripples of .18 db and a bandwidth of 425 MHz; sufficient to pass essential sideband energy, but sharply attenuating signals above 450 MHz. Inductors were realized with short lengths of straight wire and were supported by miniature high-Q trimmer capacitors at discrete points.

A 10 dB amplifier was added to increase the output power of the amplitude channel, along with a delay cable to eliminate any time skew between amplitude and polarity information. Amplification before multiplexing eliminates intermodulation distortion between the two channels.

Polarity Channel

The polarity of the beam position signal is sensed with a high-speed comparator circuit. This circuit utilizes an Advanced Micro Devices type AM685 comparator, whose power supplies have been level-shifted to give an output that is ground-referenced. A noise margin is incorporated by thresholding the input at a nominal 30 mV.

Modulation is again achieved by means of a double-balanced mixer. Here the mixer is essentially configured as an RF gate which responds to commands from the high-speed comparator. If the input signal is positive, the 675 MHz polarity carrier is present at the transmitter output. If the input is negative, the polarity carrier is gated off.

Insertion of a highpass filter in the polarity channel proved unnecessary for 2 reasons; (1) the rise and fall times of the comparator output sufficiently limited the modulation spectrum and, (2) the output power of the polarity channel was made low enough with respect to that of the amplitude channel that inter-channel interference was insignificant. The two channels are then summed in a power splitter/combiner for transmission.

Results

Figure 2 shows a typical input pulse applied to the transmitter, with figures 3 and 4 illustrating amplitude and polarity channel responses, respectively. The resultant risetime of the amplitude channel

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envelope is approximately 2 ns, while its falltime is about 2.5 ns. Similarly, the polarity channel has a risetime of 2 ns and a falltime of 3 ns.

The wideband nature of the transmitters output is depicted in figure 5; an analysis of the spectral response of the system to the pulse of figure 2. With a maximum output voltage of 1.6 V_{pp} (+14 dbm), the amplitude channel shows good modulation linearity over the entire 30 db dynamic range required by the damper system. Maximum polarity channel output is 120 mV_{pp} (-8 dbm). Significant sideband power is found over a spectrum of 50 to 850 MHz during operation in the damper system.

Acknowledgements

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References

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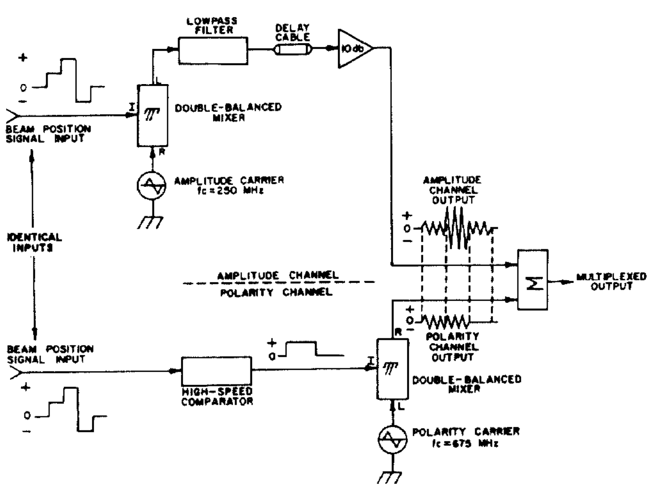

Fig. 1. Transmitter Block Diagram.

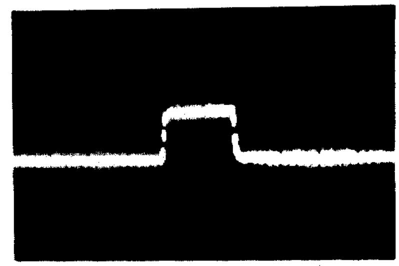

Fig. 2. Test Input Pulse.
Vertical: 2 V/div.,
Horizontal: 10 ns/div.

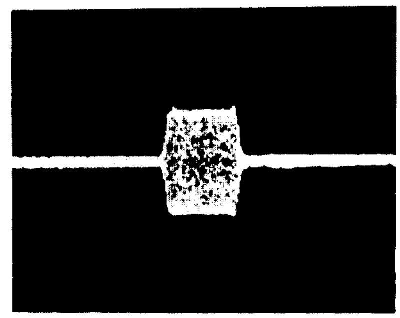

Fig. 3. Amplitude Channel Envelope.
Vertical: .5 V/div.,
Horizontal: 10 ns/div.

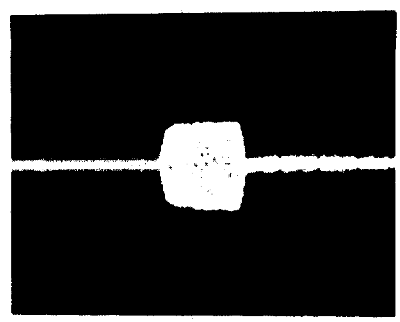

Fig. 4. Polarity Channel Envelope.
Vertical: 50 mV/div.,
Horizontal: 10 ns/div.

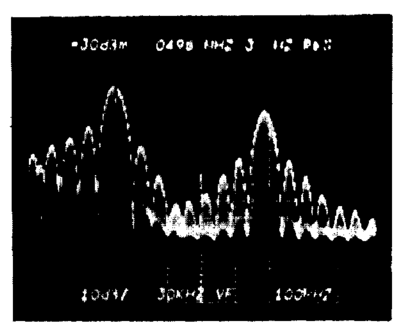

Fig. 5. Multiplexed Output Modulation Spectrum.