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Simulation of Coherent PSK Circuit for Wireless Data Communication with Zero Bit Error Rate

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Abstract: A Coherent phase-shift-keyed (CPSK) wireless data communication circuit, based on differential signaling, is simulated for error-free data recovery. The simulated circuit is tested and the results are reported, indicating error-free data recovery. In these simulation tests, data with bit rates varying from 1Kb/s to 1Mb/s are transmitted through simulated AWGN channels with channel noise variance ranging from 1 to 10,000. All the test results indicate error-free data recovery.

Index Terms: Coherent PSK, Differential signaling, Wireless communication, Zero BER data recovery.

I. INTRODUCTION

The ideal requirement of any data communication system is reception of transmitted data without any error. In the case of wireless transmission of data, suitable digital modulation techniques like ASK, FSK, PSK, DPSK, QPSK, etc. may be adopted [1]. Irrespective of the technique adopted, the noise in the channel, through which the wireless data is transmitted, corrupts the data modulated wireless carrier. As a result, the received signal, after demodulation, delivers noise-corrupted data, causing bit errors. To tackle this problem of bit errors, over the years a number of channel coding techniques have been developed using redundant bits for detection and correction of such bit errors [2]. In wired communication, differential signaling [3], is a technique in which the data bits and their complementary bits are transmitted simultaneously through a twisted pair of wires. The transmission noise, if any, will affect equally the data bits and their complementary bits. At the receiving end, the difference of the data bits and their complementary bits will eliminate the common noise, and result in error-free data bits. In this letter, we present a simulation circuit for error-free data recovery in wireless communication using the above differential signaling technique. The simulation results are also presented.

II. SIMULATION CIRCUIT

Using MATLAB/SIMULINK, a CPSK circuit is simulated for wireless transmission of data bits, using differential signaling. A suitable receiver circuit, using coherent detection, forms part of the simulation circuit for error-free (Zero BER) data recovery.

The circuit in Fig. 1. is used for the simulation of wireless data communication for data recovery with zero BER.

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In the simulation circuit, a 1GHz cosine carrier is phase-shift-keyed (PSK) by 1Mb/s data in one modulator (CPSK1). An identical cosine carrier is modulated by the complement data in another modulator (CPSK2). Both these PSK carriers are simultaneously transmitted through two identical AWGN channel blocks, simulating simultaneous wireless transmission of the carriers through the same medium. The received PSK modulated carriers are subtracted from each other. This process cancels out the common noise component and produces the error-free PSK cosine carrier modulated by the data bits, as shown below.

Data bit voltage $V_s = +1V$ for binary '1'; -1V for binary '0'

Modulation carrier = $\cos 2\pi 10^9 t$

PSK modulated carrier = + $\cos 2\pi 10^9 t$ for binary '1';
$-\cos 2\pi 10^9 t$ for binary '0'

Random noise voltage of the AWGN Channels = V_n

Received signal voltage through first AWGN channel =
$\pm \cos 2\pi 10^9 t + V_n$ ('+' for binary 1; '-' for binary'0')

Received signal through second AWGN channel = $\mp \cos 2\pi 10^9 t + V_n$ ('-' for data binary 1 ;'+' for data binary 0)

Subtractor Output $= (\pm \cos 2\pi 10^9 t + V_n) - (\mp \cos 2\pi 10^9 t + V_n) = \pm 2 \cos 2\pi 10^9 t$ *('+' for binary 1; '-' for binary 0)*

Thus the output of the subtractor is the data modulated PSK carrier, with total noise cancellation. This noise-free PSK modulated carrier is demodulated by a

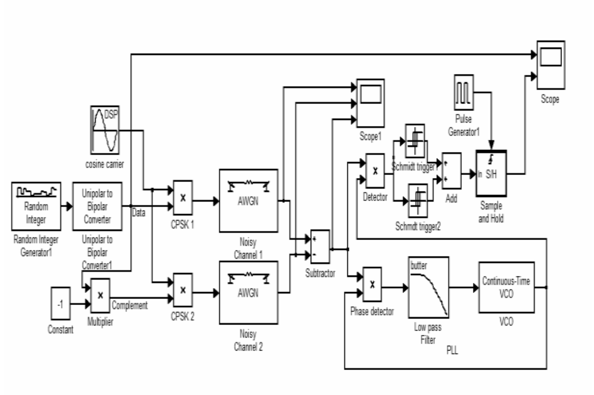

Fig. 1. Simulation Circuit for wireless data communication using CPSK

coherent cosine carrier, generated by a Phase Locked Loop (PLL), as shown in Fig. 1. The data bits, recovered after such coherent detection, may have traces of carrier in their envelope. To remove these traces, the detected bits are shaped by a pair of shunt - connected Schmidt triggers followed by a Sample and Hold circuit, as shown in Fig. 1.

The output of this Sample and Hold circuit is carrier-trace-free bipolar data bit stream. These recovered bipolar data bits are absolutely error-free as shown in Fig. 3.,Fig. 5 and Fig. 7.

III. SIMULATION RESULTS

The simulation is carried out several times for various combinations of bit rate, carrier frequency and noise variance, using MATLAB/SIMULINK. The data bit rate is varied from 1Kb/s to 1Mb/s. The carrier frequency is varied suitably from 50KHz to 1GHz. The noisy medium is simulated by AWGN blocks. The seed function and the variance of both the AWGN blocks are identically varied to simulate different noise conditions. The variance is varied from 1 to 10,000. In all these cases, for the purpose of error estimation, the recovered data is compared with the original data. In all these simulation tests, the recovered data are found to be exactly identical to the original data transmitted, indicating Zero BER These simulation test results are consolidated in Table. 1.

TABLE I Bit Error Rate for several combinations of data bit rate and noise variance

	AWGN CHANNEL NOISE VARIANCE					
DATA BIT RATE in Kb/s		**1**	**10**	**100**	**1000**	**10000**
	1	0	0	0	0	0
	10	0	0	0	0	0
	100	0	0	0	0	0
	1000	0	0	0	0	0

The waveforms for 1Mb/s bit rate with channel noise variance of 10000 are shown in Fig. 2. and Fig. 3.

In Fig. 2. the outputs of AWGN 1 and AWGN 2 corresponding to the noise affected modulated cosine carriers are shown in the first two traces of waveforms. The difference of the above two noise affected carriers is shown in the third trace of waveform. This waveform clearly shows the cancellation of noise, resulting in a PSK modulated cosine carrier.

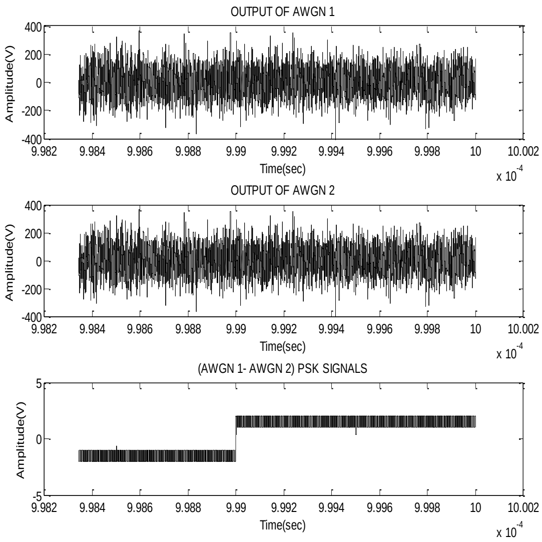

Fig. 2. Outputs of AWGN1, AWGN 2 and Subtractor for 1Mb/s data, 1GHz carrier and noise variance10000

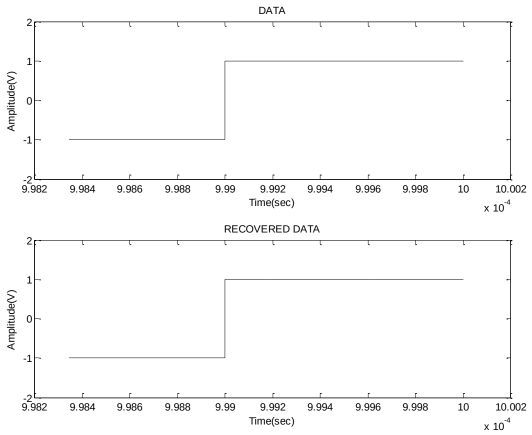

Fig. 3. Transmitted and recovered data for 1Mb/s data, 1GHz carrier and noise variance10000

In Fig. 3. the first trace of waveform is that of transmitted 1Mb/s data bits. The second trace of waveform is the recovered data bits at the output of Sample and Hold circuit. It is evident that there is no error in the recovered data bits as compared with the transmitted data bits, indicating zero BER.

Fig. 4. and Fig. 5 show the simulation results corresponding to 10Kb/s data and its complement modulating 500KHz cosine carriers transmitted through AWGN channels of noise variance of 10000. Fig. 4. shows the outputs of the AWGN channels and the subtractor output. Fig. 5. shows the transmitted data and the recovered error-free data.

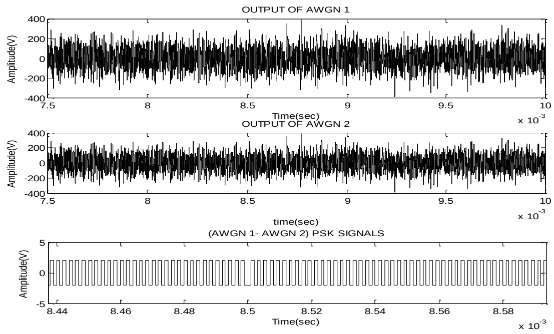

Fig. 4. Outputs of AWGN1, AWGN 2 and Subtractor for 10Kb/s data, 500KHz carrier and noise variance10000

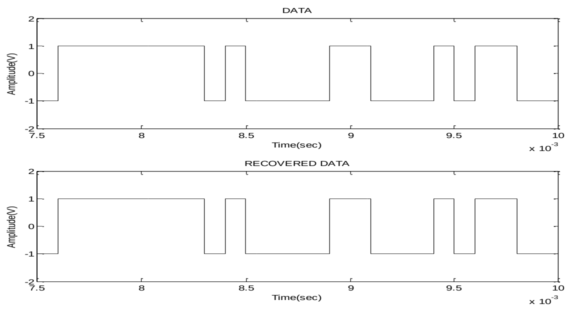

Fig. 5. Transmitted and recovered data for 10Kb/s data, 500KHz carrier and noise variance10000

Finally, a simulation with 1Kb/s data and its complement modulating 50KHz cosine carriers has also been carried out specifically to obtain clearer waveforms of test results, as shown below in Fig. 6 and Fig. 7.

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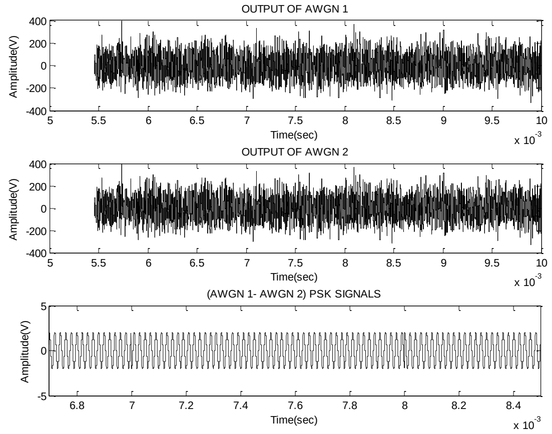

Fig. 6. Outputs of AWGN1, AWGN 2 and Subtractor for 1Kb/s data, 50KHz carrier and noise variance10000

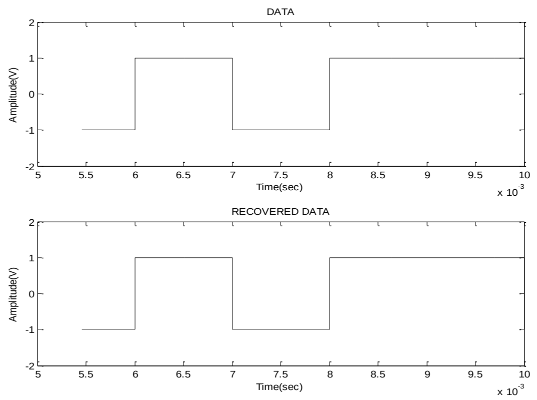

Fig. 7. Transmitted and recovered data for 1Kb/s data, 50KHz carrier and noise variance10000

IV. CONCLUSION

Although Zero BER is realized in this simulation circuit, in an actual wireless system, the co-channel interference due to identical, say 1GHz carriers is likely to result in some bit errors. Hence two different carrier frequencies, say 1GHz for data and 1.2 GHz for complement data may be used to reduce BER. Such a dual carrier system with dual band antenna is currently under construction. The corresponding test results will be reported in future.

However, it is to be noted that differential signaling requires complementary bits, equal in number to the data bits. This implies an overhead of 100% bits. Nevertheless the inherent advantage of faultless data communication with zero-bit-error will outweigh the large overhead of complementary bits, in applications like telemedicine, wherein reliable transmission of medical data is of prime concern.

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