THE BRIDGE FUNCTION TELEMETRY SYSTEM*

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ABSTRACT

Based on the theory of orthogonality, two orthogonal multiplex systems called frequency division multiplexing(FDM) and time division multiplexing(TDM) have long been developed. Therefore, many people tend to think that these two systems represent the ONLY two multiplexing methods that satisfy the orthogonal condition. However, after years of research, we've discovered a new kind of orthogonal functions called Bridge functions. The Bridge functions have the every promise of being the basis for constructing an entirely new kind of telemetry system, which has been named as sequency division multiplexing(SDM).

Since the Bridge functions are the mathematical basis of the new telemetry system, we will give a summary of the Bridge functions at first. We have successfully constructed an experimental prototype called BAM-FM system in our laboratory. The main ideas, block diagram, operational principles, and technical problems are discussed in this paper. All our work has proved that SDM has not only research interests, but also practical value.

KEY WORDS

Telemetry system, Multiplexing, Orthogonal function, Bridge functions.

INTRODUCTION

The IRIG standard for telemetry, as revised in 1986, is IRIG 106-86. This document contains the three systems: FM, PCM

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and PAM. FM is called “frequency-division multiplexing”, and both PAM and PCM are called “time-division multiplexing”. The basis of mathematics which can be used to form a telemetry system is the orthogonal functions. The sequence-division multiplexing based on Walsh functions was first introduced in 1980[1]. Another sequence-division multiplexing based on Haar functions was presented in 1983[2]. In the same year a kind of Bridge functions was introduced[3], which is a three-valued function system, only taking the values +1, -1 and 0. The Bridge functions are constructed with the concepts of sequence shift and sequence copying. As the name implies, they act like a bridge between the Walsh functions and the block pulses. In this sense, we all this three-valued system of functions the bridge functions. According to our previous experince, a new telemetry system based on bridge functions has been constructed.

THE MATHEMATICAL BASIS

It has been proved that all orthogonal function sets may, in principle, be used for multiplexing. As long as the crosstalk between the channels is minimal, the multiplex system can be formed. Expressing in mathematical terms, the conditions of orthogonality are

$$\int_{-T/2}^{T/2} f(k,\theta)\, f(j,\theta)\, d\theta = \begin{cases} 0 & k \neq j \\ 1 & k = j \end{cases}$$

where the function f ( ) can be sine of cosine, and can also be other orthogonal functions. If we can find a set of functions which is orthogonal. Then based on the functions, a new telemetry system may be constructed. Now we should introduce the Bridge functions in some detail. The first type of Bridge functions is obtained through copying after shifting, and the second type of Bridge functions is obtained by shifting after copying.

THE CONSTRUCTION OF BRIDGE FUNCTIONS

When the symmetric copying of Walsh functions and the shift mode of block pulses is combined, the construction of the bridge functions is obtained. The method is as follows.

(1) Let I represent the bridge function of order I. It can be expressed in binary code

$$i_{p-1}\ i_{p-2}\ \ldots\ i_{j-1}\ \ldots\ i_1\ i_0$$

(2) The binary number is divided into two parts.

(a) The j binary digits on the right side, $i_{j-1}\ i_{j-2}\ \ldots\ i_1\ i_0$, are used as shift information.

(b) The (p-j) binary digits on the left side are used as copying information.

(3) Sequence shift is done first, followed by sequence copying.

(a) The value of the original sequence is always +1 (+ for short) in the interval 0, in the other L-1 intervals the value is zero, where $L=2^j$.

(b) According to the shift information $i_{j-1}\ i_{j-2}\ \ldots\ i_0$, the original sequence "+" is shifted to the right side.

(c) The symmetric copying mode is used, according to the information $i_{P-1}\ \ldots\ i_j$. The copying is done one by one At the first i_{P-1} is taken as the information, then i_{P-2} is taken as the information, and so on, until p-j digits are used. The process of forming bridge functions is shown in Table I.

THE CONSTRUCTION OF COPY-SHIFT BRIDGE FUNCTIONS

It is obviously that sequence shift may be done both before and after sequence copying. If copying is done followed by shifting, a copy-shift Bridge functions will be obtained. The method of constrictions is similar to that of the first type. Table II shows the process for forming the functions Bri_w' (i,j,p,t).

ORTHOGONALITY OF SECOND BRIDGE FUNCTIONS

It can be proved that the second Bridge functions have orthogonality if certain conditions are satisfied. For simplicity, Therefore, the orthogonality in this case can be summarized as:

$$\int_0^1 bri2_y(i_1,j,p,t)bri2_y(i_2,j,p,t)dt = \begin{cases} 0 & \text{when } i_1 \neq i_2 \\ L/N & \text{when } i_1 = i_2 \end{cases}$$

That is to say when the parameters j and p are fixed and I is variable, the second Bridge functions make up an orthogonal function system.

BLOCK DIAGRAM OF THE NEW SYSTEM

The basic problem of a multiplexing system is how to transmit many information signals over a single wire or radio link and recover them without interference between channels. Non-interference between channels can be guaranteed in a multiplex system if the selected set of subcarriers are mutually orthogonal, meaning that the product of any two subcarrier waveforms integrates to zero over some characteristic interval T. Any two subcarriers P(n,t) and P(m,t) are orthogonal if they satisfy the relationship:

$$\frac{1}{T}\int_0^T P(n,t)\,P(m,t)\,dt = 0$$

The block diagram is shown in Fig.l.

THE KEY TECHNICAL POINTS

Sine there are three values for the waveform of Bridge functions which are +1, 0 and -1, it is difficult to generate them with only digital circuits. Analogue circuits as well as digital one should be used. The key point is how to make a bridge function generator. In fact there are three ways to solve the problem: software one, hardware one and the combination of software and hardware one. Multivalue logic multiplier is another key point. There are three basic types of multipliers. The first one multiplies two voltages that can assume two values only,. say +1V and -1V. This type of multiplier is implemented by logic circuits. The second one multiplies an arbitrary voltage V_1 with a voltage V_2 which can assume a few values only. The third one multiplies two arbitrary voltages. Because of the property of bridge function waveforms, we are interested in the second type multiplier.

The two problems for building a bridge telemetry system have been solved. A prototype with seven channels has been built in our laboratory.

EXPERIMENTAL RESULTS

A baseband transmission system with 7 channels has been designed and tested. It shows that the results of experiments are quite good, and the new system works well. In order to fulfill the radio transmission, the combined signal is applied to a conventional FM or AM transmitter. Naturally at the receiving terminal, a conventional FM or AM receiver is required. A FM system is here used as carrier transmission. The whole system can work properly: The frequency response is 4KHz. The crosstalk of the whole system is less than 3%, usually 1-3%. The wave distortion is also less than 3%. It is acceptable in engineering applications.

CONCLUSION

According to the theory of telemetry, the mathematical basis of a telemetry system is the orthogonal functions. The Bridge functions are orthogonal and have many advantages. With these ideas based on the Bridge functions, a prototype of a new system is constructed and tested. The result shows that the new telemetry system is reasonable not only academically but also in practice. This is an example of the combination of the theory and the practice. The new telemetry system is built in our laboratory, it also serves a good tool for further investigation.

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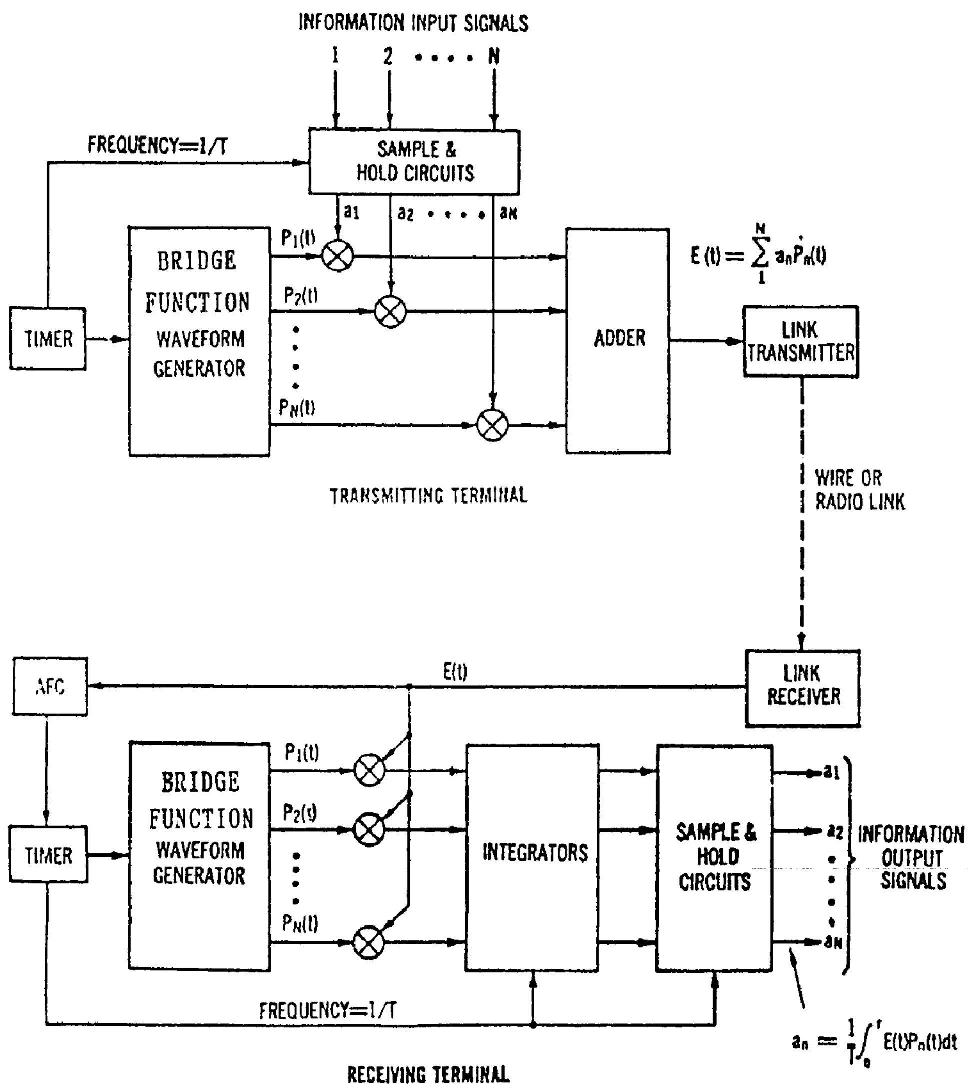

Figure 1. Block diagram of THE NEW TELEMETRY SYSTEM

TABLE I
THE PROCESS OF FORMING BRIDGE FUNCTIONS, i=0, ... , 15,
FOR THE SHIFT NUMBER j=1

order number	binary code	copy information	shift information	original sequence	sequence after shift	first copy sequence	second copy sequence	third copy sequence
i	$i_3 i_2 i_1 i_0$	$i_3 i_2 i_1$	i_0			i_3	i_2	i_1
0	0 0 0 0	0 0 0	0	+ 0	+ 0	0 +	+ 0 0 +	+00++00+
1	0 0 0 1	0 0 0	1	+ 0	0 +	+ 0	0 + + 0	0++00++0
2	0 0 1 0	0 0 1	0	+ 0	+ 0	0 +	+ 0 0 +	-00--00-
3	0 0 1 1	0 0 1	1	+ 0	0 +	+ 0	0 + + 0	0--00--0
4	0 1 0 0	0 1 0	0	+ 0	+ 0	0 +	- 0 0 -	-00-+00+
5	0 1 0 1	0 1 0	1	+ 0	0 +	+ 0	0 - - 0	0--00++0
6	0 1 1 0	0 1 1	0	+ 0	+ 0	0 +	- 0 0 -	+00+-00-
7	0 1 1 1	0 1 1	1	+ 0	0 +	+ 0	0 - - 0	0++00--0
8	1 0 0 0	1 0 0	0	+ 0	+ 0	0 -	- 0 0 +	+00--00+
9	1 0 0 1	1 0 0	1	+ 0	0 +	- 0	0 - + 0	0+-00-+0
10	1 0 1 0	1 0 1	0	+ 0	+ 0	0 -	- 0 0 +	-00++00-
11	1 0 1 1	1 0 1	1	+ 0	0 +	- 0	0 - + 0	0-+00+-0
12	1 1 0 0	1 1 0	0	+ 0	+ 0	0 -	+ 0 0 -	-00+-00+
13	1 1 0 1	1 1 0	1	+ 0	0 +	- 0	0 + - 0	0-+00-+0
14	1 1 1 0	1 1 1	0	+ 0	+ 0	0 -	+ 0 0 -	+00-+00-
15	1 1 1 1	1 1 1	1	+ 0	0 +	- 0	0 + - 0	0+-00+-0

TABLE II. THE PROCESS OF FORMING THE FUNCTIONS $Bri_w'(i,j,p,t)$

$j=2,\ p=3$

order number	binary code	copy information	shift information	original sequence	first copy sequence	second copy sequence	sequence after shift
i	$i_2 i_1 i_0$	$i_1 i_0$	i_2		i_1	i_0	i_2
0	0 0 0	0 0	0	+	+	+ +	+ + + + 0 0 0 0
1	0 0 1	0 1	0	+	+	− −	+ + − − 0 0 0 0
2	0 1 0	1 0	0	+	−	− +	+ − − + 0 0 0 0
3	0 1 1	1 1	0	+	−	+ −	+ − + − 0 0 0 0
4	1 0 0	0 0	1	+	+	+ +	0 0 0 0 + + + +
5	1 0 1	0 1	1	+	+	− −	0 0 0 0 + + − −
6	1 1 0	1 0	1	+	−	− +	0 0 0 0 + − − +
7	1 1 1	1 1	1	+	−	+ −	0 0 0 0 + − + −