United States Patent [19]
Caragliano et al.

[11] **3,863,024**
[45] **Jan. 28, 1975**

[54] DIRECTIONAL COUPLED DATA TRANSMISSION SYSTEM

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[22] Filed: **Dec. 26, 1973**

[21] Appl. No.: **427,768**

[52] **U.S. Cl.** **178/68,** 333/10
[51] **Int. Cl.** **H04l 11/00**
[58] **Field of Search**............ 178/68, 70 R, 69 R, 66; 333/6, 10; 325/38 B, 38 R, 38 A; 340/167 R, 167 A, 167 B, 167 C, 147 R, 170; 328/112, 157

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Attorney, Agent, or Firm—Harold H. Sweeney, Jr.

[57] ABSTRACT

A combination is provided of a directional coupler connected in a transmission line of a data transmission system and an encoding means for generating the data bits of information which, when coupled through the directional coupling means, produces a coupled signal having a substantially fixed width regardless of the length of the transmission line traversed and a height which diminishes comparatively slowly with the transmission line length traversed. The directional coupling means has a coupling coefficient of at least 0.5 and has an electrical length which is substantially equivalent to one quarter of a bit length of the encoded information. The encoding means for the data bits of information generate at least one of the encoded bits identified by a full cycle signal having an equal positive and negative excursion.

11 Claims, 13 Drawing Figures

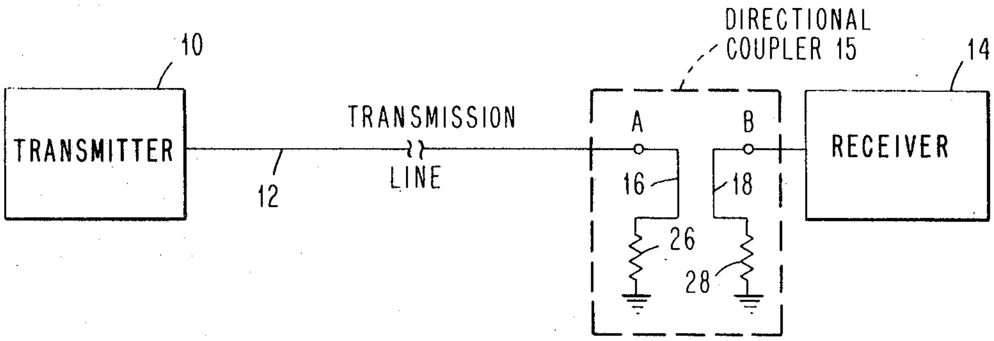


FIG. 1

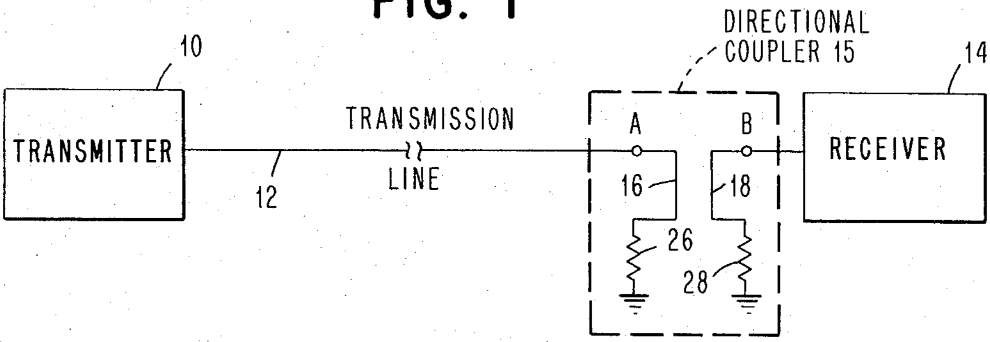
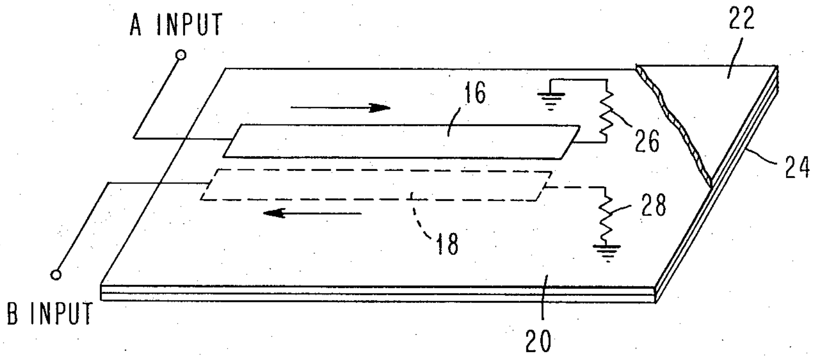


FIG. 2



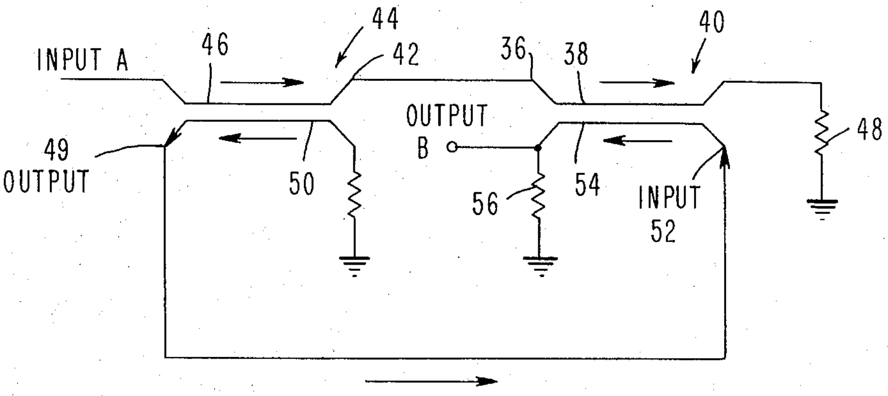


FIG. 2A

FIG. 3

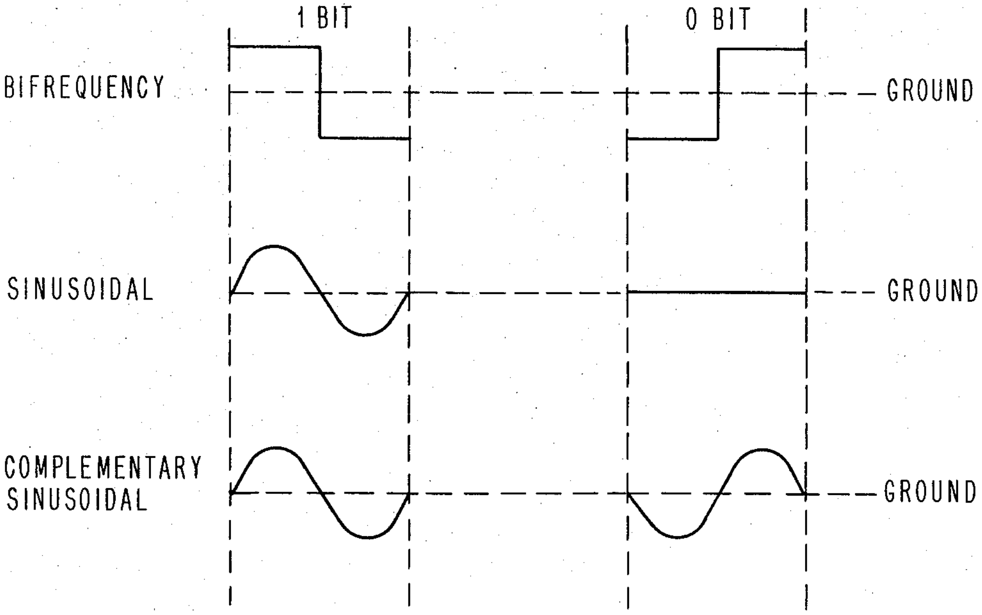

1 BIT
0 BIT
BIFREQUENCY
GROUND
SINUSOIDAL
GROUND
COMPLEMENTARY SINUSOIDAL
GROUND

FIG. 4

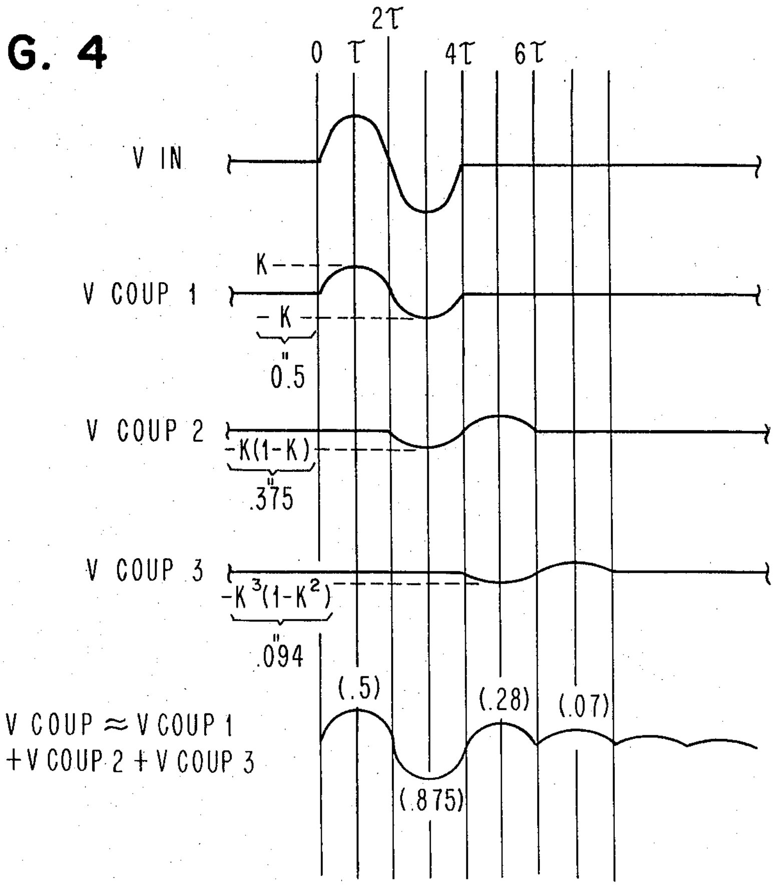
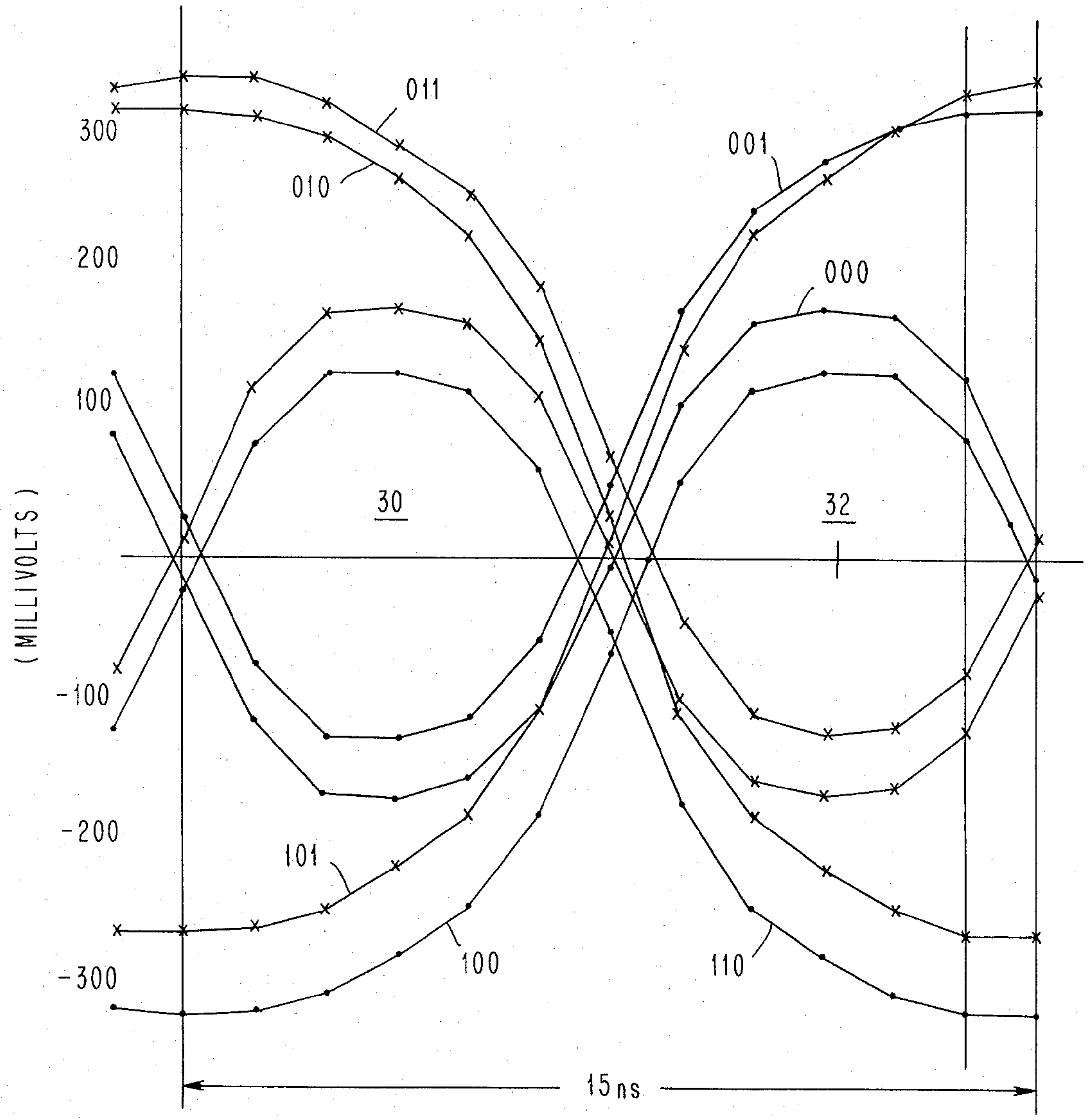

0
τ
2τ
4τ
6τ
V IN
K
V COUP 1
-K
0.5
V COUP 2
-K(1-K)
.375
V COUP 3
-K³(1-K²)
.094
(.5)
(.28)
(.07)
(.875)
V COUP ≈ V COUP 1 + V COUP 2 + V COUP 3

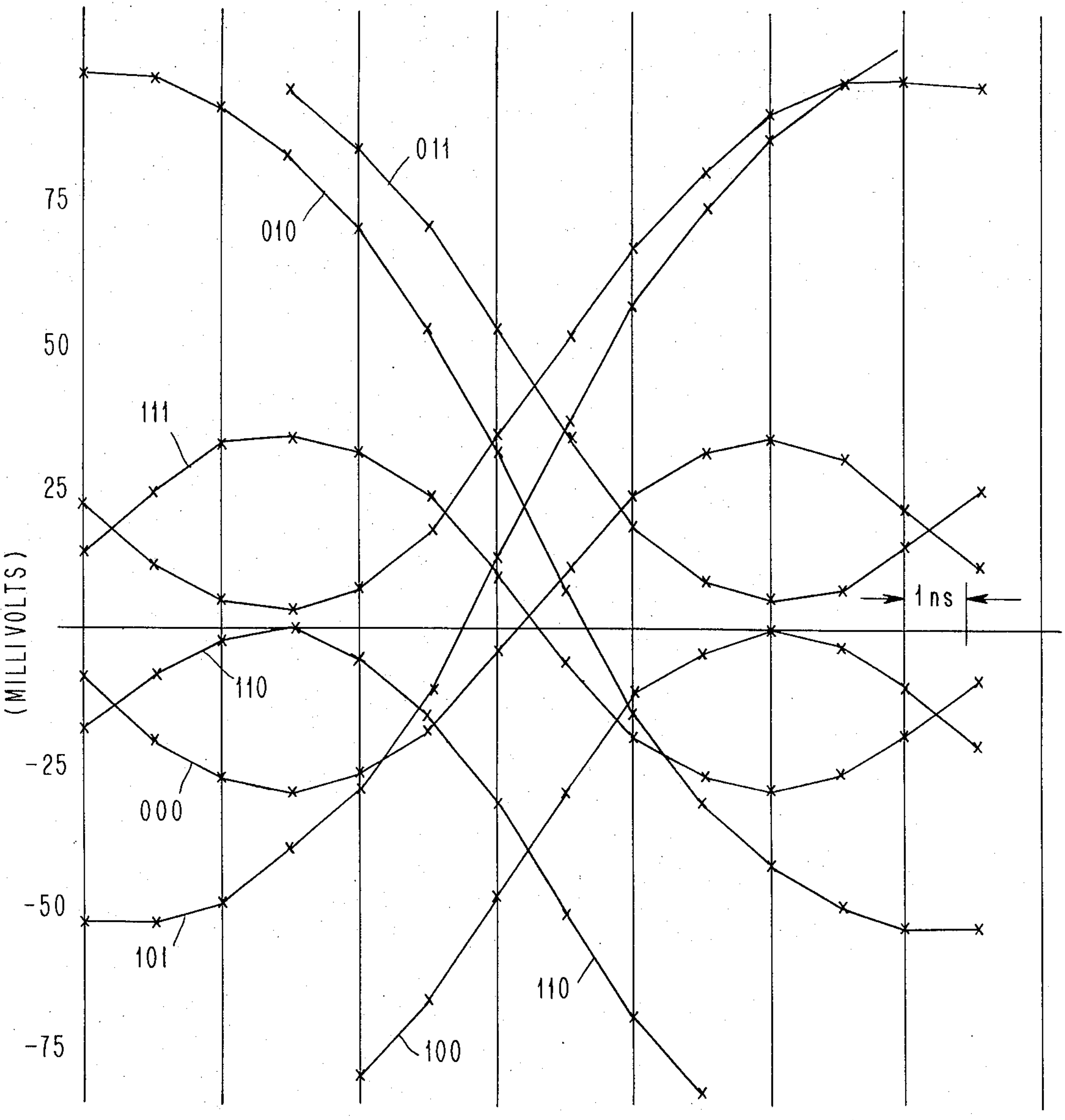
FIG. 5



BIFREQUENCY
2 VOLT P-P
INPUT
OUTPUT FOR
1500 FT CABLE

110 • –
100 • –
000 • –
001 • –
010 X –
101 X –
011 X –
111 X –

FIG. 6



3000 FT
BIFREQUENCY
NO COUPLE

FIG. 7

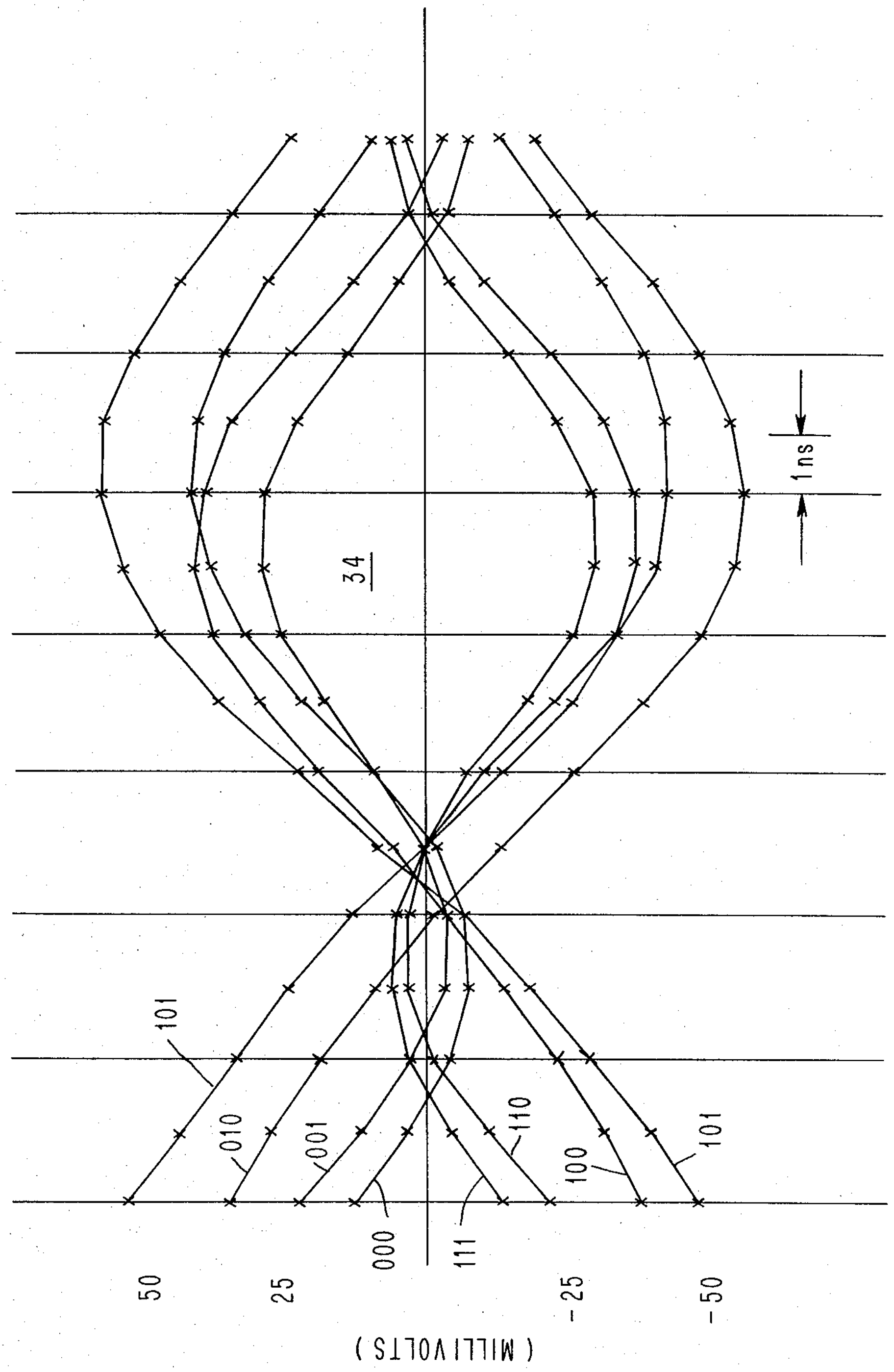
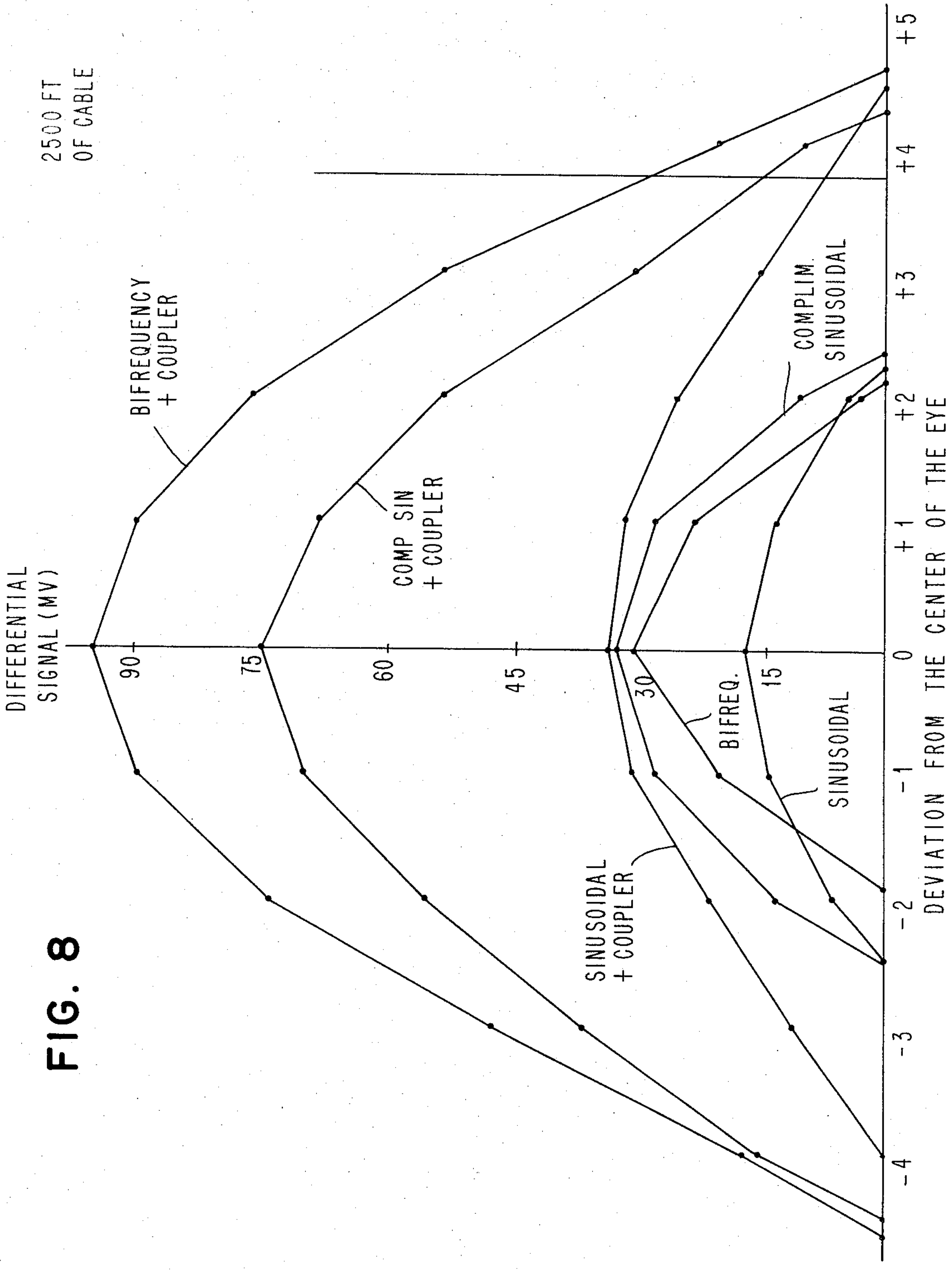


FIG. 8


2500 FT
OF CABLE
DIFFERENTIAL
SIGNAL (MV)
90
75
60
45
30
15
BIFREQUENCY
+ COUPLER
COMP SIN
+ COUPLER
COMPLIM.
SINUSOIDAL
SINUSOIDAL
+ COUPLER
BIFREQ.
SINUSOIDAL
-4
-3
-2
-1
0
+1
+2
+3
+4
+5
DEVIATION FROM THE CENTER OF THE EYE
(NANO SECONDS)

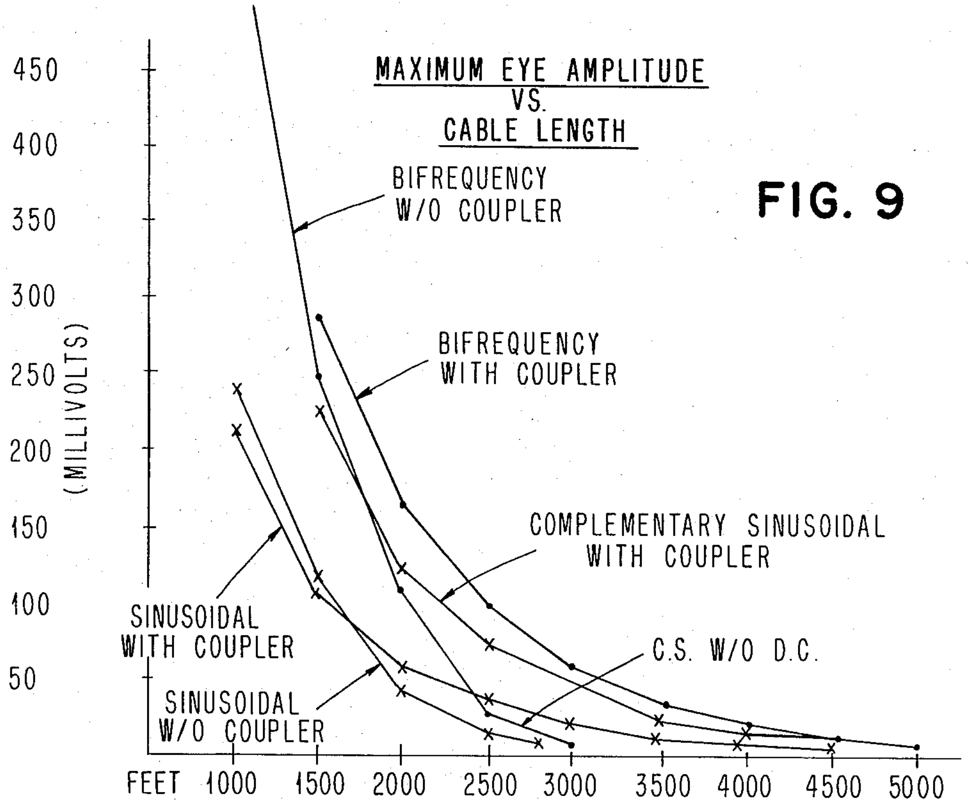

MAXIMUM EYE AMPLITUDE
VS.
CABLE LENGTH
(MILLIVOLTS)
450
400
350
300
250
200
150
100
50
BIFREQUENCY
W/O COUPLER
BIFREQUENCY
WITH COUPLER
COMPLEMENTARY SINUSOIDAL
WITH COUPLER
SINUSOIDAL
WITH COUPLER
C.S. W/O D.C.
SINUSOIDAL
W/O COUPLER
FEET
1000
1500
2000
2500
3000
3500
4000
4500
5000

FIG. 9

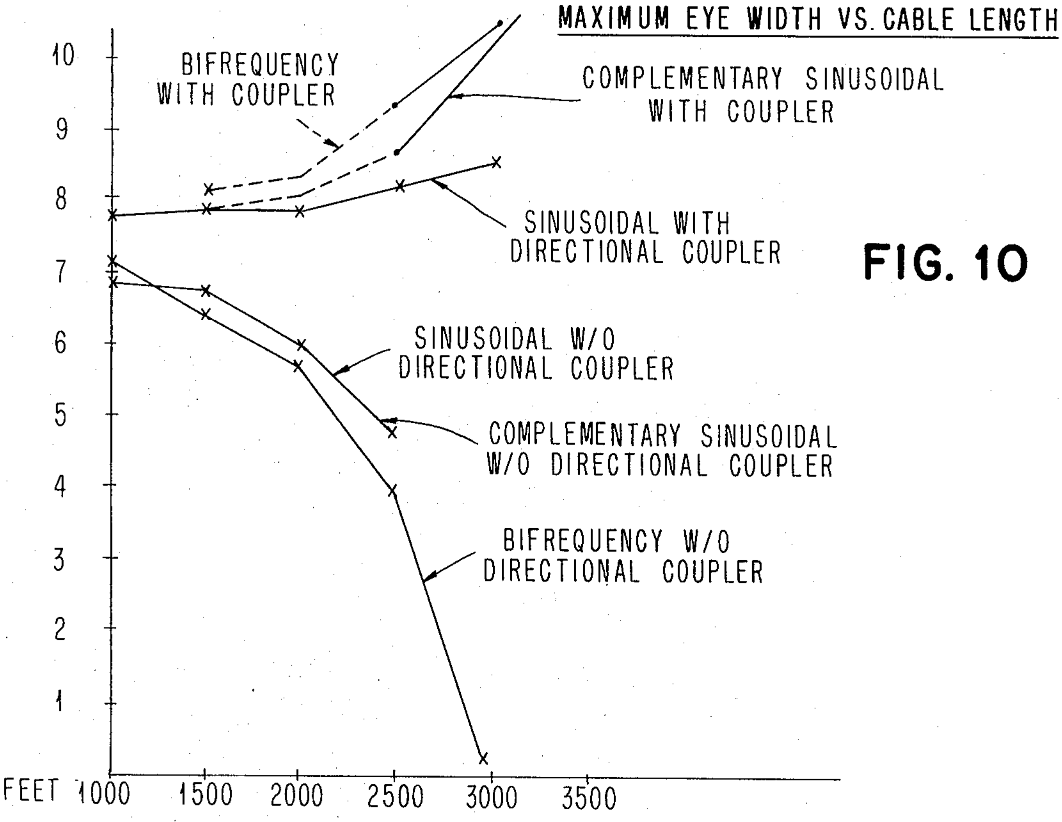

MAXIMUM EYE WIDTH VS. CABLE LENGTH
10
9
8
7
6
5
4
3
2
1
BIFREQUENCY
WITH COUPLER
COMPLEMENTARY SINUSOIDAL
WITH COUPLER
SINUSOIDAL WITH
DIRECTIONAL COUPLER
SINUSOIDAL W/O
DIRECTIONAL COUPLER
COMPLEMENTARY SINUSOIDAL
W/O DIRECTIONAL COUPLER
BIFREQUENCY W/O
DIRECTIONAL COUPLER
FEET
1000
1500
2000
2500
3000
3500

FIG. 10

FIG. 11

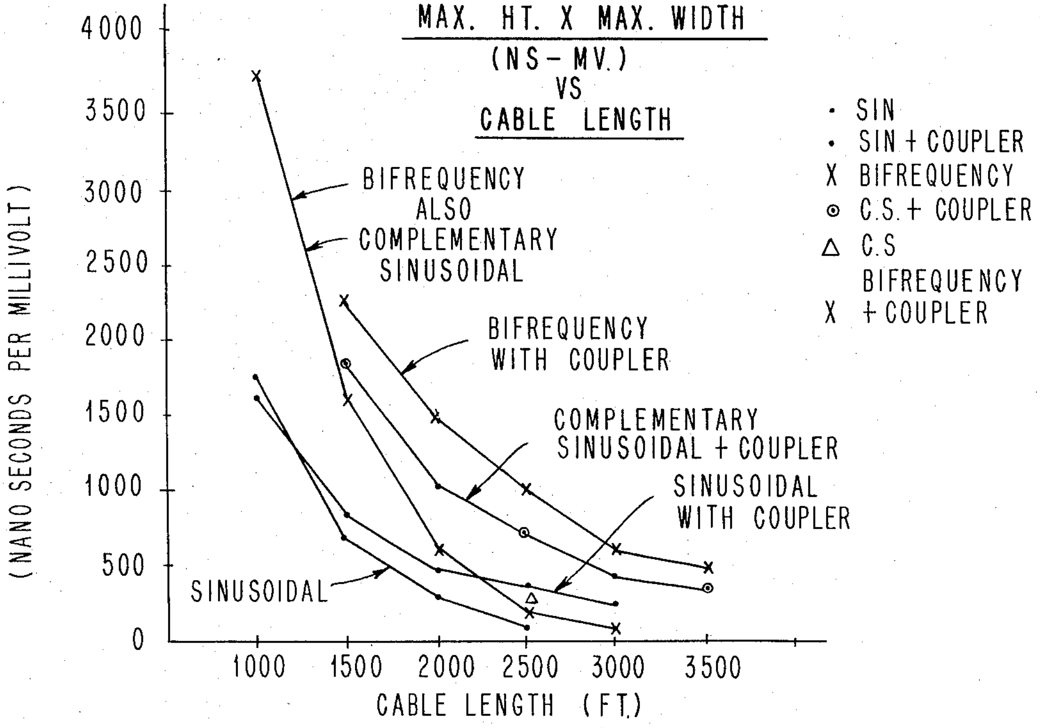
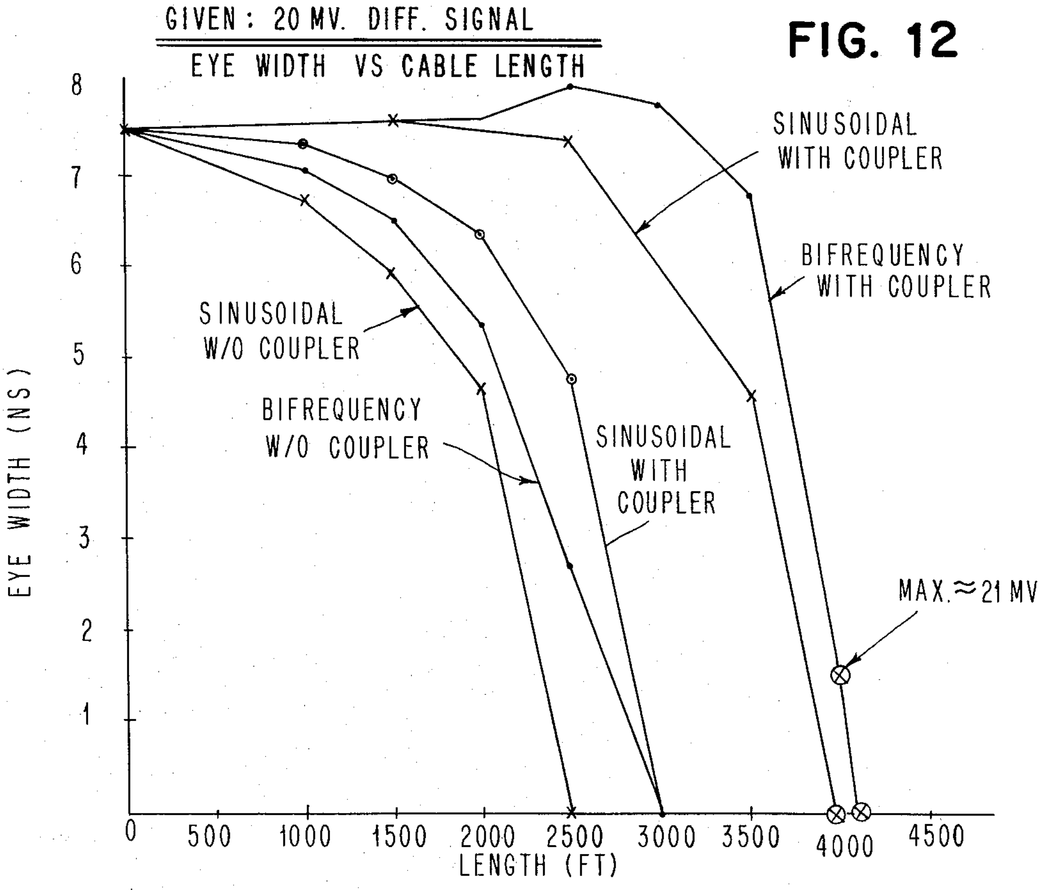

MAX. HT. X MAX. WIDTH
(NS-MV.)
VS
CABLE LENGTH
(NANO SECONDS PER MILLIVOLT)
4000
3500
3000
2500
2000
1500
1000
500
0
1000
1500
2000
2500
3000
3500
CABLE LENGTH (FT.)
BIFREQUENCY
ALSO
COMPLEMENTARY
SINUSOIDAL
BIFREQUENCY
WITH COUPLER
COMPLEMENTARY
SINUSOIDAL + COUPLER
SINUSOIDAL
WITH COUPLER
SINUSOIDAL
· SIN
• SIN + COUPLER
X BIFREQUENCY
⊙ C.S. + COUPLER
△ C.S
BIFREQUENCY
X + COUPLER

FIG. 12


GIVEN: 20 MV. DIFF. SIGNAL
EYE WIDTH VS CABLE LENGTH
EYE WIDTH (NS)
8
7
6
5
4
3
2
1
0
500
1000
1500
2000
2500
3000
3500
4000
4500
LENGTH (FT)
SINUSOIDAL
WITH COUPLER
BIFREQUENCY
WITH COUPLER
SINUSOIDAL
W/O COUPLER
BIFREQUENCY
W/O COUPLER
SINUSOIDAL
WITH
COUPLER
MAX.≈21 MV

DIRECTIONAL COUPLED DATA TRANSMISSION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to the combination of a directional coupling means connected in the transmission line of a data transmission system and an encoding arrangement which taken together provides improved data at the receiver end of the transmission line.

2. Brief Description of the Prior Art

In data transmission systems of the type where the data is transmitted along the transmission line in coded form to a receiver or utilization device, it has been found that the transmission line introduces attenuation and distortion which limits the length of the transmission line which can be utilized before signal amplification is necessary. There are a number of additional constraints which are placed upon a transmission system when intelligence data is to be transmitted. For example, some types of modulation or encoding enhance the transmission capabilities of the system. Also the signal to noise ratio is a limiting factor. Special techniques have been used to improve the data transmission, for example, pre-distortion of the signals is introduced so that the transmission line distortion will bring the data signals back to the desired amplitude and shape. Also, techniques of equalization and filtering have been used. An equalizer is a unit which usually has the exact opposite transfer characteristics of the transmission line so that the signals, after passing through the transmission line, are essentially corrected by the equalizer by putting the opposite distortion, etc., into the signal to bring it back to a desired amplitude and shape. These transmission systems also have special clocking requirements by means of which the data is maintained synchronized at various stations along the transmission line.

In present day data handling systems, transmission loops have become necessary wherein a number of input/output stations are connected. These transmission lines are called loop systems since they are usually serviced by a central host computer which transmits the data along the line where it can be picked off at each station and new information entered on the transmission line if desired. The location of the input/output stations is limited to a certain length of transmission line if the desired reliability is to be maintained. It will be appreciated, that the transmission line introduces sufficient amplitude distortion and linear phase shift to the data signals so as to limit the transmission line distance at which the receiver is capable of distinguishing the intelligence carried by the data. This distance has been improved somewhat by the use of the previously described equalizers. However, an equalizer is designed for use with a particular length of cable. Therefore, if a different length is desired, an equalizer designed for that length must be used. In other words, an equalizer designed for use with a specific transmission line length does not work as well with a transmission line length of a different length or at least of any substantial difference in length. It is not only necessary to maintain sufficient amplitude to distinguish the signal from the noise, etc., but it is also necessary to maintain sufficient signal width and height to be able to strobe the signal to detect the information and abstract the clock information.

The above mentioned disadvantages of the prior art data transmission systems are overcome by providing directional couplers in the transmission lines before the receivers which improve the resulting signal in both height and width when used with various encoding schemes. It follows, that the improvement in the signal would allow longer lengths of cable to be utilized. It will also be appreciated, that the improved signal alleviates the requirements placed upon clocking or strobing circuits at the receiver.

BRIEF SUMMARY OF THE INVENTION

The invention consists of the combination of a directional coupler connected in a transmission line of a data transmission system and an encoding means for generating the data bits of information which, when coupled through the directional coupling means, produces a coupled signal having a substantially fixed width regardless of the length of the transmission line traversed and a height which diminishes comparatively slowly with the transmission line length traversed. The directional coupling means has a coupling coefficient of at least 0.5 and has an electrical length which is substantially equivalent to one quarter of a bit length of the encoded information. The encoding means for the data bits of information generate at least one of the encoded bits identified by a full cycle signal having an equal positive and negative excursion.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram showing a data transmission system with a directional coupler located in the transmission line.

FIG. **2** is a schematic diagram showing the directional coupler of FIG. **1** in more detail.

FIG. **2A** is a schematic diagram showing two directional couplers for connecting into the transmission line.

FIG. **3** is a schematic representation showing three waveforms for representing the information in the encoded bits.

FIG. **4** shows a representative input waveform and the waveforms generated in coupling the input through the coupler to get the resultant output waveform.

FIG. **5** is a graph showing the eye pattern obtained using bi-frequency encoding after travelling through 1,500 feet of cable.

FIG. **6** is a graph showing the eye pattern obtained after travelling through 3,000 feet of cable utilizing a bi-frequency encoding.

FIG. **7** is a graph showing the eye pattern obtained after travelling through 3,000 feet of cable using the bi-frequency encoding with a coupler connected in the transmission line.

FIG. **8** is a graph showing the rate of change of the height to the width from the center of the eye after travelling through 2,500 feet of cable for various encoding schemes.

FIG. **9** is a graph of the maximum eye pattern amplitude versus the cable length for various encoding schemes.

FIG. **10** is a graph showing the plot of the maximum eye width versus the cable length for various encoding schemes with and without the directional coupler.

FIG. **11** is a graph showing the plot of the maximum height times the maximum width versus the cable length for various encoding schemes with and without the directional coupler.

FIG. **12** is a graph showing the plot of eye width versus cable length for various encoding schemes with and without the directional coupler.

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, there is shown a data transmission system in which the data is put on the transmission line **12** by a transmitter **10** and is utilized or received from the transmission line **12** by a receiver **14.** In the transmission line **12** before the receiver **14**, there is located a directional coupler **15**, the use of which in connection with the encoding selected forms the invention of this application.

The directional coupler depicted in FIG. **2** is a strip line directional coupler wherein two parallel adjacent printed circuit strip lines are separated a short distance by a material having an appropriate dielectric constant. This arrangement is located between two ground planes which are inductively and capacitively coupled so that the edges of a first pulse, of fast rise and fall time characteristics, propagating along one line, produces a positive pulse and a negative pulse in the other line. The lines are back-coupled or directional in that the thus produced pulses propagate along the second line in a direction opposite to the direction in which the first pulse propagates along the first line. The energy transferred between the coupling segments of the two element directional coupler is affected by the various physical characteristics of the directional coupler such as the length, width and distance between the coupling segments. The two conductive segments **16** and **18** are shown extending parallel to one another and separated by a nonconductive sheet of material **20** such as epoxy glass having an appropriate dielectric constant. A nonconductive sheet of material is also located above the top conductor and below the bottom conductor. These conductors and separating sheets are located between the two ground planes **22** and **24** which usually consist of sheets of copper arranged one above the top conductor **16** and one below the bottom conductor **18** separated therefrom by the respective non-conductive sheet. The first line or coupling segment **16** has an input A located at one end and a terminating resistance **26** located at the other end. As can be seen from FIG. **2**, the input A receives the encoded data being transmitted on the transmission line **12**, which data travels along the coupling segment **16** from left to right towards the terminating resistor **26.** The terminating resistor **26** matches the coupling segment to the characteristic impedance of the transmission line **12.** The coupling of the encoded data signal takes place along the coupling segment **16** to the coupling segment **18.** The signal coupled into coupling segment **18** travels in the opposite direction to the signal travelling along the coupling segment **16** as shown by arrows in both segments. The coupled signal passes from the directional coupler at the output terminal B and is received by the receiver **14.** Similarly, coupling segment **18** at the right end thereof has a terminating resistor **28** which matches the coupling segment to the characteristic impedance of the transmission line **12.** The coupler operation depends upon the steepness of the incident pulse rise and fall. The width or duration of the pulse produced by the coupling is determined by the length L of the two segments **16** and **18** in parallel. The performance of the coupler is related to the impedances offered to signals on the transmission lines and the coupling ratio, which are determined mainly by the distance between the coupling segments in the coupled region and the dielectric constant of the material separating the two. It has been determined that coupling segments of electrical length τ will produce a pulse having a time duration equal to 2 τ. For example, a 1-volt amplitude input signal applied to the input terminal A of coupling segment **16** when the coupler has a coupling coefficient K of 0.5 and an electrical length τ of 2 nsec, will produce an output pulse having a time duration of 4 nsec and a pulse amplitude of one-half a volt.

The directional coupler described above is found to produce the desired enhancement of the data transmitted along the transmission line where the coupler has an electrical length τ equal to one-fourth of the bit time and when the data is encoded such that the information is represented by bits at least one of which has a positive and negative swing over a full cycle. For example, in FIG. **3**, three known encoding schemes are shown for the information bits **1** and **0**, all of which exhibit the desired waveform enhancing when used with the particular directional coupler. The bifrequency encoding shows the 1 bit as a positive voltage for a half cycle followed by a negative voltage for the rest of the cycle and the zero bit as just the opposite, that is, a negative signal for a half cycle followed by a positive signal over the rest of the cycle. It should be noted that the bifrequency encoding scheme is a nonreturn-to-zero type of encoding. The sinusoidal encoding shows a sinusoidal signal starting at zero and going full cycle to 360° for representing the one bit and shows no signal representing the zero bit. The complementary sinusoidal encoding is shown as a full sine wave representing the one bit and the opposite thereof representing the zero bit. These encoding schemes are used in data transmission systems because they introduce bits from which the information can be extracted. It should be appreciated that these encoding schemes produce pulses whose characteristics are dependent on which information bit, a zero or one, precedes and follows it. Thus, we have an information bit which can be zero or one and which can be preceded and followed by a bit which can be zero or one. Thus, we have 2^3 or eight possibilities. The eight combinations are as follows: 111, 110, 101, 100, 011, 001, 010, and 000.

Referring to FIG. **4**, there is shown a sinusoidal voltage input signal which is preceded by a zero and followed by a zero. As previously mentioned, the zero is represented in sinusoidal encoding by no signal. This sinusoidal encoded signal is sent into the coupler of the present invention which is tuned to have an electrical length τ equal to one-fourth of a bit time. The directional coupler transformation characteristic may be expressed in the time domain by the following Laplace Transform:

$$\frac{V\text{ coupled }(s)}{V\text{ in }(s)} = k - k(1-k^2)e^{-2\tau s}\sum_{n=0}^{\infty} k^{2n}e^{-2n\tau s}$$

where: Vcoupled equals the voltage of the coupled pulse, Vin equals the voltage of the input pulse, k equals the coupling coefficient of the coupler, and τ equals the electrical length of the coupling region. Since the coupling coefficient k is a constant less than unity and τ is a fixed constant, the coupling output is expressable as the sum of the delayed, attenuated and phase shifted reproductions of the input. As previously mentioned, k is equal to 0.5 and τ is equal to one-fourth of a bit time in this invention. The various pulses produced in the second coupling segment as the result of Vin, shown in FIG. 3, are shown as Vcoupled 1, Vcoupled 2 and Vcoupled 3. These three waveforms combine as shown in the waveform Vcoupled of FIG. 4 which is the output of the coupler. It can be seen, that Vcoupled is approximately equal to Vcoupled 1 + Vcoupled 2 + Vcoupled 3. It should be obseved that the first swing of the output waveform of Vcoupled is half the amplitude of the positive swing of Vin. This is in accordance with the coupling ratio of 0.5. However, the negative swing is 0.875 in amplitude. There has been an energy trnasformation from the positive swing of the input waveform to the negative swing of the output waveform. This fact is very important to the enhancement of the encoded data signals obtained by the use of the directional coupler in this invention.

In data transmission systems, in order to extract the information, it is necessary to strobe the data pulses. This so-called strobing requires that the pulse carrying the information is of sufficient width and amplitude to be easily detected. The actual strobing is done on the second half cycle of the data waveform. Referring to FIG. 4, it can be seen that the use of the directional coupler enhances the second half of the cycle as shown in the Vcoupled waveform. A convenient way of analyzing the encoded data pulses on a transmission line is to superimpose the eight combinations of the waveform at a particular point in the transmission line. These superimposed waveforms are called "eye patterns." A typical eye pattern is shown in FIG. 5 where it can be seen that the first eye **30** and second eye **32** each extend 100 millivolts above and below the 0 millivolt line. Each eye extends in width approximately 7½ nanoseconds. This particular eye was developed using a bifrequency type of encoding and a 2 volt peak-to-peak input signal reproduced after travelling through 1,500 feet of cable. As previously mentioned, 8 waveforms are shown, all at the same point, representing all eight combinations of three pulses having two possibilities each (2^3). Each of the eight possibilities 000 through 111 are clearly identified in FIG. 5. It can be seen from FIG. 5, that the second half of the eye as well as the first half has a clearly defined height and width for extracting the information as to whether the waveform represents a one or zero.

Referring to FIG. 6, it can be seen that the eye pattern has deteriorated to such a point that the information carried by the waveform cannot be extracted therefrom reliably. The eyes **30** and **32** no longer clearly exist. This eye pattern was obtained from a bifrequency encoding identical to the waveform used to produce FIG. 5. However, this waveform eye pattern was developed after travelling through 3,000 feet of cable. The cable adversely effects the signal and, accordingly, the length of cable through which the signal can travel and still retain extractable information is limited.

Referring now to FIG. 7, there is shown the eye pattern obtained after travelling through 3,000 feet of cable using the same bifrequency encoding as was used in FIG. 6. The eye **34** is quite clearly defined in both height and width. However, the first eye in the pattern has been for all practical purposes destroyed. Referring back to FIG. 4, it should be recalled that there is an energy transformation which takes place from the first eye to the second eye in a data waveform when a directional coupler is introduced. In this particular case, FIG. 7, a coupler is introduced into the transmission line at the end of the 3,000 feet of cable. Thus, the contrast between the eye pattern of FIG. 6 and FIG. 7 is quite clear. It should be remembered, that the second half of the eye is used for the strobing to obtain the information from the waveform. The eye patterns of FIG. 6 and FIG. 7 were developed using the same bifrequency encoded data travelling in equal lengths of cable, the only difference being the introduction of the directional coupler in the case of FIG. 7. The enhancement of the signal produced by the introduction of the directional coupler with this type of data encoding is clearly represented. It has also been found that longer lengths of cable can be used which results in a diminishing of the height of the second eye of the pattern but not the width. Thus, the width of the second eye is not affected by the length of the cable traversed.

The improvements achievable through the use of the directional coupler in the transmission line in combination with the encoding scheme are depicted in FIG. 8, which provides plots for six cases of interest for comparison. The six cases chosen are the three encoding schemes, the bifrequency, sinusoidal, and complementary sinusoidal, previously discussed in FIG. 3. Each of these schemes is plotted with and without the directional coupler for comparison purposes. FIG. 8 shows the differential signal in millivolts which can be obtained from the second half of the eye pattern after travelling through 2,500 feet of cable using the previously described encoding schemes with and without a directional coupler. More specifically, the rate of change of the height with distance measured along the width from the center of the eye is shown. For any deviations about the center of the eye, utilization of the coupler produces a significantly greater differential signal. For example, at plus or minus 1 ns from the center of the eye the bifrequency scheme without the directional coupler provides a differential signal of approximately 21 m.v. In comparison, the bifrequency scheme with the directional coupler provides a differential signal of 90 m.v. at plus or minus 1 ns from the center of the eye. This is a better than 4-to-1 improvement in the available differential signal. Similar comparison can be made for the other encoding schemes. With the bifrequency encoding and with the coupler, a greater than 4 times improvement is obtained. With the sinusoidal encoding and with a directional coupler in the line, approximately a 2.3 time improvement is obtained. Similarly, with the complementary sinusoidal encoding and a directional coupler in the line an approximately 2.6 time improvement can be obtained.

FIG. 9 shows the plot of maximum eye amplitude versus cable length for each of the six previously mentioned cases. For example, given a 50 m.v. maximum eye amplitude requirement, the following maximum lengths are achievable with each of the given schemes:

sinusoidal encoding without the directional coupler — 2,000 feet
sinusoidal encoding with the directional coupler — 2,200 feet
bifrequency encoding without the directional coupler — 2,350 feet
complementary sinusoidal without the coupler — 2,350 feet
complementary sinusoidal encoding with a directional coupler — 2,900 feet
bifrequency encoding with a coupler — 3,200 feet.

It should be noted, that the complementary sinusoidal plot without the coupler is only shown for a single case at 2,500 feet. For other points between 1,000 feet and 2,500 feet it should be closely approximated by the bifrequency case. It can be seen from this Figure, that the bifrequency scheme, for example, has a 36 percent cable length increase possibility when used with the directional coupler.

FIG. **10** shows the maximum eye width versus the cable length for each of the previously mentioned six cases. For example, given a 6 nanosecond minimum width requirement the following maximum lengths are achievable with each of the schemes:

the bifrequency encoding without the coupler — 1,800 feet
sinusoidal encoding without the coupler — 2,000 feet
complementary sinusoidal encoding without the coupler — 2,000 feet
bifrequency encoding with the coupler — 5,000 feet
sinusoidal encoding with the coupler — 4,500 feet
complementary sinusoidal encoding with the coupler — 5,000 feet.

The bifrequency encoding scheme, for example, produces a 280 percent cable length increase without causing the eye to go below a minimum width requirement when a directional coupler is used.

FIG. **11** shows a plot of the product of the maximum width and maximum height versus cable length for each of the six cases mentioned. This plot provides a measure of the eye's area for the various cases previously mentioned as a function of length of cable. Looking at the plot of the bifrequency data encoding it can be seen that after 3,000 feet of cable there is no appreciably eye measurement obtainable. However, in the case of the bifrequency plot with the coupler there is an appreciable area indicated for 3,500 feet of cable.

FIG. **12** is a plot of the eye width versus cable length for an aribtrarily chosen minimum eye amplitude of 20 m.v. The same six cases are plotted consisting of the three encoding schemes with and without directional coupler. The complementary sinusoidal plot without the coupler is not shown since it is approximated by the bifrequency without the coupler plot. If a minimum eye width of 6 ns is required, the maximum achievable distance for the six cases is as follows:

1. sinuosidal without the coupler — 1,350 feet
2. bifrequency encoding without the coupler — 1,650 feet
3. complementary sinusoidal encoding without the coupler — 1,650 feet
4. sinusoidal encoding with a coupler — 2,050 feet
5. complementary sinusoidal with a coupler — 3,200 feet
6. bifrequency encoding with a coupler — 3,650 feet

Examining the graph, it can be seen that the bifrequency encoding with a directional coupler exhibits an increase of cable length which can be utilized of 120 percent as compared to the length of cable limit obtained using the bifrequency encoding without the directional coupler.

If it should be desired to increase the height of the second eye in the eye pattern, this can be done by using a second directional coupler connected to the first directional coupler so as to further enhance the coupled signal. Referring to FIG. **2**A there is shown the schematic diagram of a second embodiment of the directional coupler which can be connected into the transmission line **12** of FIG. **1.** This further embodiment consists of a second directional coupler **40** connected to the first directional coupler **44.** As can be seen, the connections are made such that the input **36** to the first coupling segment **38** of the second coupler **40** is connected to the output **42** of the first coupling segment **46.** The other end of the first coupling segment **38** of the second coupler **40** is connected to ground through a terminating resistor **48** introducing an impedance which is the equivalent of the characteristic impedance of the transmission line to which the coupler is connected. The output **49** of the second coupling segment **50** of the first coupler **44** is connected to the input **52** of the second coupling segment **54** of the second coupler **40** as shown in FIG. **2**A. The other end of the second coupling segment **54** of the second coupler **40** is connected to ground through a terminating resistance **56** which is equivalent to the characteristic impedance of the transmission line. The output of the directional coupler means is taken from output B at the left end of second coupling segment **54.** This output is connected to point B in the transmission line **12** of FIG. **1.**

In operation, the input signal to the first coupling segment **46** of the first coupler **44** is coupled to the second coupling segment travelling in the opposite direction as shown by the arrows. This coupled pulse is applied to the second coupling segment **54** of the second coupler **40** at the input end **52** thereof and travels toward the terminated end and the output as shown by the arrow. The input signal travels to the right in the first coupling segment **38** of the second coupler **40** as shown by the arrow. This causes coupling of a signal to the second coupling segment **54** travelling in the left hand direction which enhances the signal already travelling therein as a result of the connection to the output **49** of the second segment **50** of the first coupler **44.** It has been found that a pair of directional couplers **44, 40** connected as shown in FIG. **2**A and each of which has a coupling coefficient of 0.5 and an electrical length τ of one-fourth of the bit time will produce an output pulse which has an amplitude approximately 1.5 times the input signal to the second coupler. As a result of connecting a two coupler arrangment of this type into the transission line the eye pattern obtained has a higher amplitude than those previously shown. In other words, the height using the second directional coupler can be increased by a factor of 1.5. It should be noted, that this does not affect the width of the eye pattern. This type of height enhancement is useful in connection with obtaining the clocking information from the data. The clocking information is extracted from the area between the two eyes of the eye pattern. More specifically, it is dependent upon the slope of the second eye pattern. It will be appreciated that increasing the height of this second eye of the eye pattern will considerably increase the slope thus making the extraction of the clocking signal more reliable.

Further directional couplers can be added to the pair of couplers mentioned above with connections similar to those used for connecting directional coupler **40** to **44.** These additional couplers will, if properly connected, further enhance the input signal to give increased amplitude to the second eye of the eye pattern.

The use of directional coupler means in the data transmission line of a data transmission system conveying encoded information bits of data provides a means of enhancing the encoded data signals. Accordingly, the prior limitations as to cable length are relaxed. Also, the signal to noise ratio is improved and the sensitivity of the receiver-amplifier can also be relaxed. Because of this invention, a number of the other parameters can also be relaxed, for example, the power requirements are not as great since a smaller signal can actually be utilized in the system because of the increased detection capabilities. Likewise, the limitations on the characteristics of the cable used can also be relaxed since the signal used with the directional coupler is not cable sensitive but is more dependent on the signal frequency and wave length.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and detail may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. In a data transmission system having a transmitter and receiver connected through a transmission line for conveying encoded data bits of information the combination of:

directional coupling means located in said transmission line and an encoding means for generating the data bits of information which when coupled through said directional coupling means produces a coupled signal having a substantially fixed width regardless of the length of transmission line traversed and a height which diminishes comparatively slowly with transmission line length traversed;

said directional coupling means having a coupling coefficient of at least 0.5 and having an electrical length which is substantially equivalent to one quarter of a bit length;

said encoding means for the data bits of information generating at least one of the encoded bits identified by a full cycle signal having an equal positive and negative excursion.

2. In a data transmission system according to claim **1,** wherein said directional coupler means connected in said transmission line comprises:

a first coupling segment connected at one end thereof to a first length of said transmission line and terminated at the other end thereof in a resistance equal to the characteristic impedance of transmission line;

a second coupling segment connected at one end thereof to a second length of said transmission line and terminated at the other end thereof in a resistance equal to the characteristic impedance of said transmission line;

said first and second coupling segments being coextensive with said terminated ends adjacent one another and located between ground planes and at a distance from one another to give the desired coupling from the first coupling segment to the second coupling segment in a backward direction.

3. In a data transmission system according to claim **1,** wherein said transmission line for conveying encoded data represented by bits of information is a cable.

4. In a data transmission system according to claim **1,** wherein said encoding means is represented by two bits of information, each extending for a full cycle having an equal positive and negative excursion in a nonreturn to zero form, one bit consisting of a positive signal for a half cycle followed by a negative signal for a half cycle, the other bit consisting of a negative signal for a half cycle followed by a positive signal for a half cycle.

5. In a data transmission system according to claim **1,** wherein said encoding means is represented by two bits of information, each extending for a full cycle in a return to zero form; one bit consisting of a sinusoidal waveform starting with a positive half cycle followed by a negative half cycle, the other bit consisting of the absence of a signal for a full cycle.

6. In a data transmission system according to claim **1,** wherein said encoding means is represented by two bits of information, each extending for a full cycle in a return to zero form, one bit consisting of a sinusoidal waveform starting with a positive half cycle followed by a negative half cycle, the other bit consisting of a sinusoidal waveform starting with a negative half cycle followed by a positive half cycle.

7. In a data transmission system according to claim **1,** wherein said directional coupling means is a strip line directional coupler consisting of printed circuit first and second coupling segments separated by a material having a high dielectric constant.

8. In a data transmission system according to claim **2,** wherein said first coupling segment and said second coupling segment are of the same length, width, and thickness and are located equally distant from one another along the width dimension.

9. In a data transmission system according to claim **7,** wherein said strip line directional coupler is located between and separated from thin copper sheets forming ground planes therewith by high dielectric constant material.

10. In a data transmission system according to claim **1,** wherein said directional coupler means comprises a first and second directional coupler, each having a first and second coupling segment,

the input end of said first coupling segment of said first directional coupler is connected to the transmission line connected to the transmitter so as to receive said encoded data bits of information, the other end of said first coupling segment of said first coupler is connected to the input end of the first coupling segment of said second coupler, the output end of said first coupling segment of said second coupler having a resistor connected thereto to ground providing an impedance equal to the characteristic impedance of the transmission line;

the second coupling segment of said first coupler has the output end connected to the input end of the second coupling segment of said second coupler; and said output end of said second coupling segment of said second coupler is connected to the transmission line connected to the transmission line connected to the receiver.

11. In a data transmission system according to claim **1,** wherein said directional coupler means comprises a plurality of directional couplers, each having a first and second coupling segment;

said first coupling segments of said plurality of directional couplers are connected in series to the end of said transmission line connected to the transmitter;

said second coupling segments of said plurality of directional couplers are connected in series but each having the input and output thereof reversed with respect to said first coupling segments so that the signal coupled from said first coupling segments travels in the opposite direction in said second coupling segments;

the output from the last second coupling segment of said plurality of directional couplers is connected to the transmission line connected to the receiver, the coupled signal being enhanced in amplitude by each of said plurality of couplers.

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