

PATENT SPECIFICATION

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(54) IMPROVEMENTS IN AND RELATING TO FLAT CABLE

(71) We, AMP INCORPORATED, a corporation organised and existing under the laws of the State of New Jersey, United States of America, of Eisenhower Boulevard, Harrisburg, State of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to flat cable and in particular to a modification of or an improvement in the flat cable described and claimed in the applicant's Patent No. 1,315,907.

Patent No. 1,315,907 describes and claims a flat cable comprising a plurality of spaced, parallel signal conductors lying in the same plane, a flat shield member of electrically conductive material lying in a plane parallel to but spaced from the plane of the signal conductors, elongate slots being formed in the shield member, each slot being formed opposite and extending parallel to the length of a signal conductor to decrease the capacitance between each signal conductor and the shield member, and a dielectric in the space between the signal conductors and the shield.

It has been found that a problem exists during the manufacture of flat cables according to Patent No. 1,315,907. It is difficult, because of the photographic processes involved, to ensure parallel registration of the signal conductors and the slots during the photo-etching process utilised to manufacture the desired signal conductor shapes. Consequently, skewing of the signal conductors relative to their respective slots results. The skewing results in the production of signal attenuation along the signal conductor. If a particular signal conductor is skewed relative to its associated elongate slot in a serpentine manner, skewing is periodic and energy is coupled into the shield member which produces high attenuation at wavelengths corresponding to the periodicity of the skewing.

According to the present invention, a flat cable comprises a plurality of spaced, parallel

signal conductors lying in the same plane, a flat shield member of electrically conductive material lying in a plane parallel to but spaced from the plane of the signal conductors, a dielectric in the space between the signal conductors and the shield member, and a plurality of spaced, elongate slots formed in the shield member, the slots being arranged in rows and columns, each row being formed opposite and extending parallel to the length of a signal conductor, the material of the shield member between adjacent columns defining shunt conductors.

An embodiment of the invention will now be described, by way of example, reference being made to the Figures of the accompanying diagrammatic drawings in which:—

Figure 1 is a plan view of one end portion of a flat, flexible cable;

Figure 2 is an enlarged cross-section on the line 2—2 through a portion of the cable of Figure 1;

Figure 3 is a view of the underside of the cable of Figure 1;

Figure 4 is an R.F. signal attenuation curve of a cable according to the present invention;

Figure 5 is an R.F. attenuation curve of a prior art cable showing attenuation of the cable as a function of frequency;

Figure 6 shows R.F. signal attenuation curves of a prior art cable showing attenuation due to skewing as a function of cable length; and

Figure 7 is a graph showing time domain reflectometry curves of the impedance characteristics of a prior art cable.

As shown in Figures 1 to 3, a flat, flexible cable 10 includes a plurality of spaced, parallel, ribbon-like signal conductors 12 lying in a single plane each terminating in a contact pad 11.

A ground plane or flat shield member 16 of electrically conductive material lies in a plane parallel to but spaced from the plane of the signal conductors 12. The signal conductors 12 are separated from the shield member 16 by a dielectric 13 of insulating

material such as polyethylene terephthalate. The dielectric 13 is transparent and can be seen only in the cross-section of Figure 2. Two cover sheets 14 and 15 of similar insulating material encase the conductors 12, shield member 16 and the dielectric 13.

The shield member 16 is formed with elongate slots 18 devoid of electrically conductive material. The slots 18 are arranged in rows and columns, each row being formed and extending parallel to the length of a signal conductor 12. By altering selectively the width of the slots 18 the capacitance between the signal conductors 12 and the shield member 16 can be changed without requiring a change in the thickness of the dielectric 13 or a change in the dielectric constant of this material.

Additionally, at each end of the cable 10, the shield member 16 is formed with a transversely extending aperture 24 which is devoid of conductive material. The aperture 24 is positioned opposite the contact pads 11 to facilitate assembly of the cable 10 to a connector (not shown).

Along the length of the cable 10 the rows of slots 18 are parallel to each other and are separated by thin, parallel strips of conductive shield member material, hereinafter referred to as ground conductors 20. The ground conductors 20 are parallel but offset with respect to the signal conductors 12. The signal conductors 12 and the ground conductors 20 run the length of the cable 10.

Across the width of the cable 10 the slots 18 are separated into columns by a plurality of shunt conductors 22 of electrically conductive shield member material. The shunt conductors 22 run substantially perpendicular to the ground conductors 20. The width W of each of the shunt conductors 22 is chosen so as to keep the resistance relatively low, for example, less than .01 ohms and so that the capacitance of the ground conductors is not greatly affected and the impedance made too low. For example, if L equals the centre-to-centre spacing between the shunt conductors 22 along the length of the cable 10 then a preferable ratio of W/L would be less than or equal to a pproximately 0.1.

The upper frequency limit may also be determined as a function of the spacing L between the shunt conductors 22. When the spacing is such that the distance L is equal to a half wavelength then the upper frequency may be determined as follows:—

$$f_H = \frac{v}{\lambda} = \frac{v}{2L}$$

where

v = the speed of electromagnetic wave propagation in the cable

For example, where W equals 20 mils and

L equals 250 mils the upper frequency equals approximately 14.8×10^8 Hz. At this frequency all of the reflections from the signal conductor due to the shunt conductors 22 combine in a manner which essentially produces a stopband. In actual operation, the frequency transmitted by the cable 10 would be chosen to be well below this upper frequency limit. Conversely, if L is chosen to be a quarter wavelength then the frequency

$$f_H = \frac{v}{4L}$$

is a passband frequency at which the signals transmitted by the cable 10 will not be attenuated by the shunt conductors

In general the spacing between the shunt conductors 22 should be chosen to be a small fraction of the shortest wavelength signal to be carried by the cable 10. Based on the above formulae, in one embodiment, the preferred centre-to-centre spacing between the shunt conductors is chosen to be substantially less than

$$L' = \frac{v}{2f}$$

where

v = the speed of electromagnetic wave propagation in the cable and

f = the highest frequency of the signals expected to be transmitted by the cable.

Although in the above description it has been assumed that substantially continuous signals are transmitted by the cable 10, the cable is also suitable for transmitting pulse signals. In such a case, the equivalent frequencies (in GHz) of f and f_H for use in the above described formulae may be obtained by dividing the factor .35 by the rise time of the pulses (in nanoseconds).

Referring now to Figure 4, the R.F. attenuation curve of a 50 ohm flat cable constructed according to the invention is illustrated. The shunt conductors 22 were spaced 250 mils apart and the cable length was 5.5 feet. As is apparent from the Figure, there is no resonant attenuation "dip" as in the curves of the prior art cables depicted in Figure 6 to be discussed.

In order to reduce the effect of the shunt conductors 22 at any one frequency it may be desirable for some applications to vary the spacing along the length of the cable.

The advantages of the flat cable of the present invention will be appreciated by reference to Figures 5 to 7 relating to prior art cables.

Referring to Figure 5, the attenuation of a cable as a function of the frequency of the transmitted signal is shown. The zero

reference line is the output voltage derived from the signal generator without interposing a cable section. The attenuation is thus measured in dB with respect to the zero reference line. At a frequency which is in resonance with the skewing periodicity the attenuation increases, i.e. the distance to the zero reference line increases sharply as indicated in the Figure.

The magnitude of this resonant attenuation is dependent to some degree on the length of the cable. In Figure 6 it can be seen that, for example, the greatest attenuation occurs at approximately 103.7 MHz in a cable 2.20 metres long.

Figure 7 shows a time domain reflectometry plot in which the abscissa is calibrated in time, which is directly related to the distance along the cable, and the ordinate is the reflection co-efficient. In general, time domain reflectometry (TDR) sends a fast risetime step along a line or circuit and looks at the reflection as it comes back. When measuring impedance, it produces a picture or graph representing the impedance of the line as it is averaged by the highest frequencies of the step along its length. Since the horizontal axis of the graph is distance along the line, it is possible to locate and identify the impedance of the elements of the line, such as lengths of cable, connectors and other electrical components. The vertical axis can be read as impedance or as reflection coefficient (ν) as marked.

As is known to those skilled in the art, the reflection coefficient (ν) is the ratio of the amplitude of the reflected voltage to the amplitude of the incident voltage. The reflection coefficient is related to the terminating impedance (Z_L) any point on the line by the equation:

$$Z_L = \frac{1 + \nu}{1 - \nu} \times Z_0$$

where Z_0 is the characteristic impedance of the cable. Thus the impedance at any point along the line is a second order function of the reflection coefficient at that point.

The plots in Figure 7 thus represent the impedance along a signal conductor of a prior art flexible cable under three conditions. Curve R_s represents the impedance between the material of the shield member on either side of a signal conductor into which energy is coupled due to skewing. Curve R_1 results from taking the impedance between the material of the shield member on one side of a signal conductor and the signal conductor the shield member on the other side of the signal conductor being removed. Curve R_2 shows the TDR curve resulting when the material of the shield member responsible for curve R_1 is removed from the

cable configuration and the effective impedance is provided by the material of the shield member on the other side of the signal conductor. The curves R_1 , R_2 and R_s thus represent the impedance as a function of length for the same cable. An inverse variation in the effective impedance is thus produced by skewing.

By combining the curves R_1 and R_2 it becomes obvious that since the impedance mismatch occurs at approximately the same location on the cable with respect to the two different portions of the shield member and the impedance mismatches are of opposite magnitudes and tend to cancel each other out. This cancelling phenomenon has heretofore masked the problem of signal coupling due to skewing.

The phenomenon of the impedance mismatch due to skewing with respect to the two different portions of the shield member was not readily discoverable. In fact when a number of cable prototypes were fabricated and tested by the applicant, the test results appeared to show a consistent impedance match over the lengths tested.

Testing of randomly selected lengths of cable also did not readily discover the skewing effects present in the cable. The skewing effect was discovered only by continued testing of various lengths of the cable.

WHAT WE CLAIM IS:—

1. A flat cable comprising a plurality of spaced, parallel signal conductors lying in the same plane, a flat shield member of electrically conductive material lying in a plane parallel to but spaced from the plane of the signal conductors, a dielectric in the space between the signal conductors and the shield member and a plurality of spaced, elongate slots formed in the shield member, the slots being arranged in rows and columns, each row being formed opposite and extending parallel to the length of a signal conductor, the material of the shield member between adjacent columns defining shunt conductors.

2. A flat cable as claimed in claim 1, in which the shunt conductors are substantially perpendicular to the signal conductors.

3. A flat cable as claimed in claim 2, in which the ratio of the width of each shunt conductor to the spacing between adjacent shunt conductors in a direction parallel to the signal conductors is less than or equal to 1 to 10.

4. A flat cable as claimed in claim 2 or 3, in which the spacing between adjacent shunt conductors varies along the length of the cable.

5. A flat cable as claimed in claim 2, in which the spacing between adjacent shunt conductors is a fraction of the wavelength of the signals to be transmitted by said cable.

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reference line is the output voltage derived from the signal generator without interposing a cable section. The attenuation is thus measured in dB with respect to the zero reference line. At a frequency which is in resonance with the skewing periodicity the attenuation increases, i.e. the distance to the zero reference line increases sharply as indicated in the Figure.

The magnitude of this resonant attenuation is dependent to some degree on the length of the cable. In Figure 6 it can be seen that, for example, the greatest attenuation occurs at approximately 103.7 MHz in a cable 2.20 metres long.

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where Z_0 is the characteristic impedance of the cable. Thus the impedance at any point along the line is a second order function of the reflection coefficient at that point.

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cable configuration and the effective impedance is provided by the material of the shield member on the other side of the signal conductor. The curves R_1 , R_2 and R_3 thus represent the impedance as a function of length for the same cable. An inverse variation in the effective impedance is thus produced by skewing.

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2. A flat cable as claimed in claim 1, in which the shunt conductors are substantially perpendicular to the signal conductors.
3. A flat cable as claimed in claim 2, in which the ratio of the width of each shunt conductor to the spacing between adjacent shunt conductors in a direction parallel to the signal conductors is less than or equal to 1 to 10.
4. A flat cable as claimed in claim 2 or 3, in which the spacing between adjacent shunt conductors varies along the length of the cable.
5. A flat cable as claimed in claim 2, in which the spacing between adjacent shunt conductors is a fraction of the wavelength of the signals to be transmitted by said cable.



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6. A flat cable as claimed in claim 5, in which the spacing between adjacent shunt conductors is substantially equal to L where:

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$$L = \frac{v}{4f}$$

where

f =the frequency of the signals to be transmitted by the cable;

and

10 v =the speed of electromagnetic wave propagation in said cable.

15 7. A flat cable as claimed in claim 5, in which the spacing between adjacent shunt conductors is substantially less than L' where:

$$L' = \frac{v}{2f};$$

v =the speed of electromagnetic wave propagation in said cable;

and

f =the highest frequency of the signals transmitted by said cable.

8. A flat cable constructed and arranged substantially as described with reference to and as illustrated in Figures 1 to 3 of the accompanying drawings.

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