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INTERSHEATHS BETWEEN CABLE BRAIDS

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SUMMARY

The screening efficacy of a double braided cable can be improved by the thickening of the insulating intersheath between the braids and by reducing its dielectric constant. Improvement also accompanies an increase in the power factor of the intersheath, however, this is only significant at the higher radio frequencies. It is shown to be important that the radial thickness of the intersheath be uniform around the circumference in order that the two braids be concentric.

Departmental Reference: Rad 1081

CONTENTS

1 INTRODUCTION

In many radio frequency cables which have a second wire braid applied outside the outer conductor in order to improve the screening of the cable, the two braids are separated by an insulating intersheath. It is the purpose of this Report to discuss the function of this intersheath and consider its optimum design. The design principles are applied to a consideration of cables Uniradio No.92 and 115 to BS 2316 which are the largest and smallest cables of this type listed in that specification. It is concluded that certain modifications could produce a marked improvement in their screening efficacy.

2 TRANSFER IMPEDANCE

The term 'screening efficiency' or better 'screening efficacy' which is widely used to describe the quality of a screen serves the purpose of easy description but it is not easy to quantify. For this reason the concept of 'transfer impedance' has been introduced. In order to quantify the process of the leakage of electromagnetic energy from one circuit it is necessary to specify the circuit into which the energy is transferred. The mechanism of transfer is equivalent to an impedance element common to both circuits. This is illustrated in Fig.1 in which Circuits 1 and 2 are linked by a common impedance Z_T defined as the transfer impedance. This functions in the following way, as the source in Circuit 1 passes a current I through Z_T a voltage V_T is generated across Z_T and this voltage drives a current around Circuit 2.

In the case of a coaxial cable the outer conductor acts as the common element between the coaxial pair which forms the equivalent to Circuit 1 and the outer circuit into which the circuit leaks. It is necessary to consider the transfer impedance per unit length of cable. As shown in Fig.2 it is the ratio of the voltage developed across unit length of the outside of the cable screen, to the current flowing on the inside of the screen. It is evident that, at frequencies so low that the distribution of current is substantially uniform throughout the screen (that is the skin effect is not appreciably developed) Z_T will be equal to the resistance per unit length of the cable screen.

3 THE SCREENING OF DOUBLE BRAIDS

In some cables such as Uniradio No.54, 92, 114 and 115 the outer screen consists of two braids separated by an intersheath of PVC. Such a cable is illustrated in Fig.3. The leakage of energy from the coaxial pair within S" into the region outside S' can be considered as taking place in two steps, first the transfer into the space between S' and S" and the transfer from the circuit S'S" into the outer circuit defined by the cable surroundings. Thus the current I' flowing on the inside of the inner screen S' will have associated with it a voltage V_T' per unit length for which $V_T' = Z_T'I'$. This voltage will drive a current around the circuit S'S" through the impedances Z_L which load each end. At frequencies for which the length of cable is an appreciable fraction of a wavelength the intermediate circuit S'S" must be considered as a transmission line of characteristic impedance Z_0'. In order to avoid resonances in this line it is necessary to either make each Z_L equal to Z_0' or to have so lossy a material between S' and S" that any marked resonance is damped out.

Consider now the transfer of energy from the transmission line S'S" into the region outside S". This will arise from the generation of an external voltage V_T''/unit length associated with the current I" driven in the circuit S'S" by the voltage V_T'/unit length on the outside of S'. This current I" will be inversely proportional to the characteristic impedance Z_0' and will decrease indefinitely as the diameter of S", and so Z_0', increases. Hence the screening efficacy can be increased indefinitely by increase in the thickness of the intersheath. It is also evident that as the Z_0' is inversely proportional to $\sqrt{k'}$ where k' is the dielectric constant of the intersheath, the screening efficacy is inversely proportional to k'.

It is now necessary to consider how to calculate Z_0'. For the present study the question of what is the value of Z_0' when the braids are in contact will be evaded and the assumption made that in every case the intersheath thickness will be at least 2½ times the diameter of a braiding wire. On this basis values of Z_0' have been calculated for cables based on Uniradio No.115 and 92 with different thicknesses of intersheath. For each arrangement $10 \log_{10}(Z_0')^2$ has been taken as a measure of the screening efficacy expressed in dB above an arbitrary zero. These values are plotted against intersheath thickness in Fig.4.

It is useful to consider these increases in screening efficacy which accompany thickening the intersheath in terms of the percentage increase in the overall diameter of the cable. In Fig.5 the same screening data have been plotted against percentage increase in cable diameter. In calculating the increases in cable diameter allowance has been made for the increase of the thickness of the outer cable sheath with the increase in its inner diameter following the principles of IEC Publication 96.0. From Fig.5 it is seen that for Uniradio No.115 while an increase in intersheath thickness from 0.020 inch to 0.040 inch would increase the screening by 4.7 dB (a factor of 295%) it would increase the cable diameter by only 14%, and the cross section by 21%. For Uniradio No.92 an increase in intersheath thickness from 0.040 inch to 0.080 inch would improve the efficacy by 4.8 dB for an increase in diameter of 16% and cross section of 26%.

In practice it is not possible to have an air filled gap between the sheaths and the dielectric constant will be significantly greater than unity, thus for an intersheath of polythene $k' = 2.3$ and for one of PVC k' will equal 6.0. Thus it will be seen that neglecting differences in power factor the screening efficacy of a cable will be increased by a factor of 6.0/2.25 or 4.2 dB merely by substituting polythene for the usual PVC of the intersheath and the use of an expanded polythene of $k' = 1.45$ would give an improvement of 6.2 dB.

Thus by a modification of the material and thickness of the intersheath it would be possible to increase the screening efficacy of the cable. If an intersheath of expanded polytheme of 0.060 inch thickness were substituted for the 0.030 inch PVC layer in Uniradio No.115 the screening efficacy would be increased by 10.6 dB. Similarly a change to an expanded polythene intersheath of 0.080 inch in Uniradio No.92 would result in an improvement of 11.0 dB.

So far attention has been concentrated upon the characteristic impedance of the transmission line between S' and S", now its attenuation must be considered. It is possible to imagine special cases bearing little connection with normal practice in which attenuation in this transmission line would cause a decrease in screening efficacy, but in the vast majority if not in all practical systems the attenuation reduces the current circulating in S'S", and improves the screening efficacy, in as much as the attenuation arises from dielectric loss in the intersheath and not as resistive loss in the braid.

It is not possible to quote an increase in screening efficacy for an increase in the power factor of the intersheath material. This is because the power factor determines the attenuation per unit length and the total attenuation thus depends upon the length of the cable. All that can be said is that in general the greater the power factor of the intersheath material the better. Uniradio No.92 has an intersheath with a specified attenuation between braids of at least 0.6 dB/ft at 1 MHz.

It is instructive to consider the attenuation which could be expected from the use of the normal sheathing grade of PVC as a dielectric between the braids. Taking the power factor of PVC sheathing as 0.090 and the dielectric constant as 6.0 and using the expression

$$\alpha = 2.77 \times 10^{-6} f\sqrt{k}p \quad \text{dB/100 ft}$$

where f is frequency in Hertz
and p is the power factor of the sheath

one arrives at figures of 1965 dB/100 ft at 3000 MHz and 0.655 dB/100 ft at 1 MHz. These lead one to the conclusion that at 1 MHz the attenuation plays a negligible part in the screening process while its contribution to the screening efficacy is important at a frequency of 3000 MHz.

4 THE CONCENTRICITY OF THE INTERSHEATH

If the inner and outer cylindrical surfaces of the intersheath depart from being coaxial, then the screening efficacy will be adversely affected. This is because currents will pass from one braid wire to another at their crossing points and this will increase the effective resistance of the braid by the addition of contact resistances. This deterioration will not be very marked in a new cable, but will develop as the cable ages and the contact resistances increase.

It is not easy to give a quantitative account of this effect however the basic elements of the mechanism are illustrated in Fig.6. In this figure are shown a coaxial cable and one in which the conductors are eccentric. In the former the charge and current distributions are uniform around the outer conductor and wherever two wires approach a crossing they will bring equal currents and take equal currents away. Thus their resultant will be parallel to and in opposition to the current in the inner conductor - this is a pre-requisite for screening. In the case of the eccentric cable the charge and current will be greater along the line AA and less along the line BB. As a result in general wires approaching contacts will carry differing currents and if the non-uniform current distribution is to be maintained the excess current on one wire must be transferred to the other.

It is instructive to note that in the case of Uniradio No.115 the Specification BS 2316 permits a minimum thickness of 0.015 inch and maximum of 0.045 inch. With an intersheath eccentric to these limits the current density on one side of the cable would be three times that on the other, and contact resistance effects would be expected.

5 CONCLUSIONS

As is usual when engineering parameters are under discussion few hard and fast conclusions can be drawn about the optimum design of intersheaths. Thus it is clear that the screening efficacy is improved by:-

a increasing the thickness of the intersheath

b lowering the dielectric constant of the intersheath

c increasing the power factor of the intersheath

The first two methods are of general application but the importance of the third depends upon the system in which the cable is used. Thus for a system using a short length of cable at say 1 MHz the attenuation in the intersheath would not be important while at a frequency of 3000 MHz this attenuation would play an important part in determining the efficacy of screening. Because of this dependence upon frequency it is not possible to give a general answer to the question of whether or not a given increase in power factor which was accompanied by a given increase in dielectric constant would be advantageous.

In illustration of these methods of improvement the cable Uniradio No.115 will be taken as an example. This cable has an intersheath of nominal thickness 0.020 inch. If this were increased to 0.040 inch the screening efficacy would be increased by about 4.7 dB or 295% at the cost of increasing the overall diameter by 14% or cable cross sectional area by 21%. This would appear to be a worthwhile exchange.

A further conclusion is that the present limits on the intersheath dimensions should be tightened in order to ensure that the two braids of a double screened cable are nearly equispaced around their circumference. This will ensure that the currents flowing between the braids will be evenly distributed between the braiding wires so that contact resistance effects will be minimised. It is likely that the cost of meeting closer limits would be small compared with the high cost of applying the two braided screens, and by ensuring that they operated efficiently this extra cost would show a worthwhile return.

SYMBOLS

f	frequency in Hz
I	current flowing in a cable
I'	current flowing in inner screen of a double screened cable
I''	current flowing in outer screen of a double screened cable
k	dielectric constant of a cable dielectric
k'	dielectric constant of an intersheath
p	powerfactor
V	voltage between conductors of a coaxial cable
V_T	voltage/unit length induced on the outside of a screen
Z_L	load impedance
Z_0	characteristic impedance of a cable
Z'_0	characteristic impedance of the coaxial system between two braids
Z_T	transfer impedance
α	attenuation/unit length

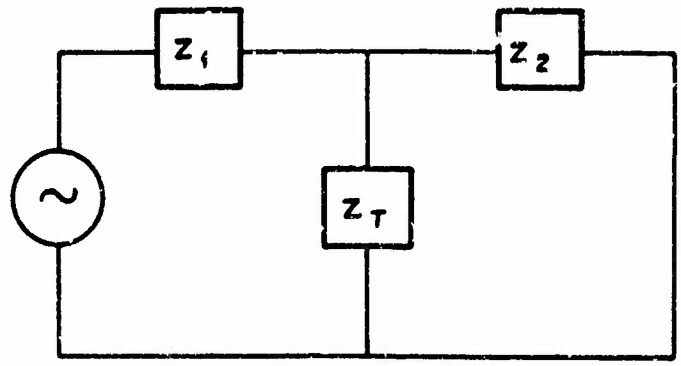

Fig.1 The coupling of two circuits by a transfer impedance

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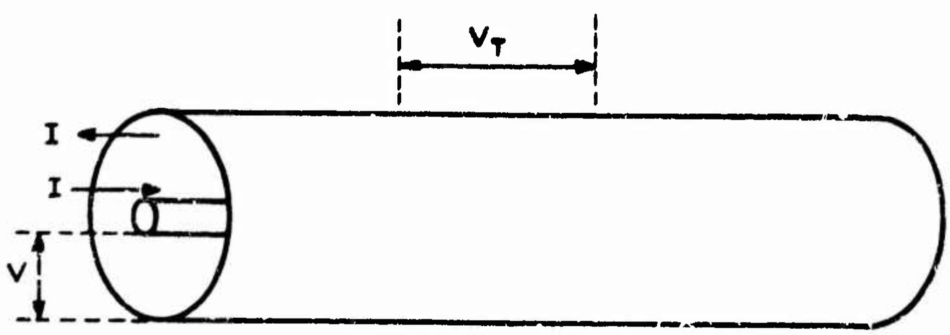
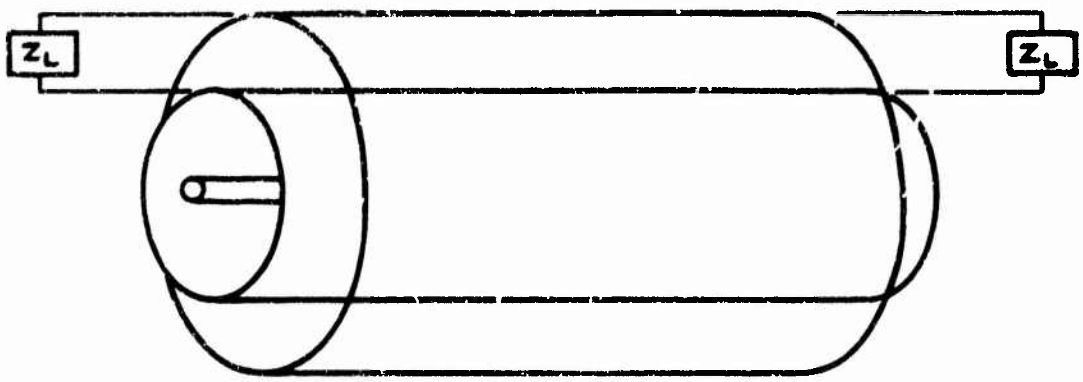


The application of a voltage V to the cable produces a current I such that $I = V/Z_0$

The passage of I along the outer conductor is associated with a voltage V_T across unit length of the cable.

The ratio of I and V_T defines the transfer impedance, Z_T, through the equation $Z_T = V_T/I$

Fig.2 The transfer impedance of a cable screen



S' and S'' are the inner and outer screens

Z_L Z_L are the terminating impedances between S' and S''

Fig. 3 A double screened cable

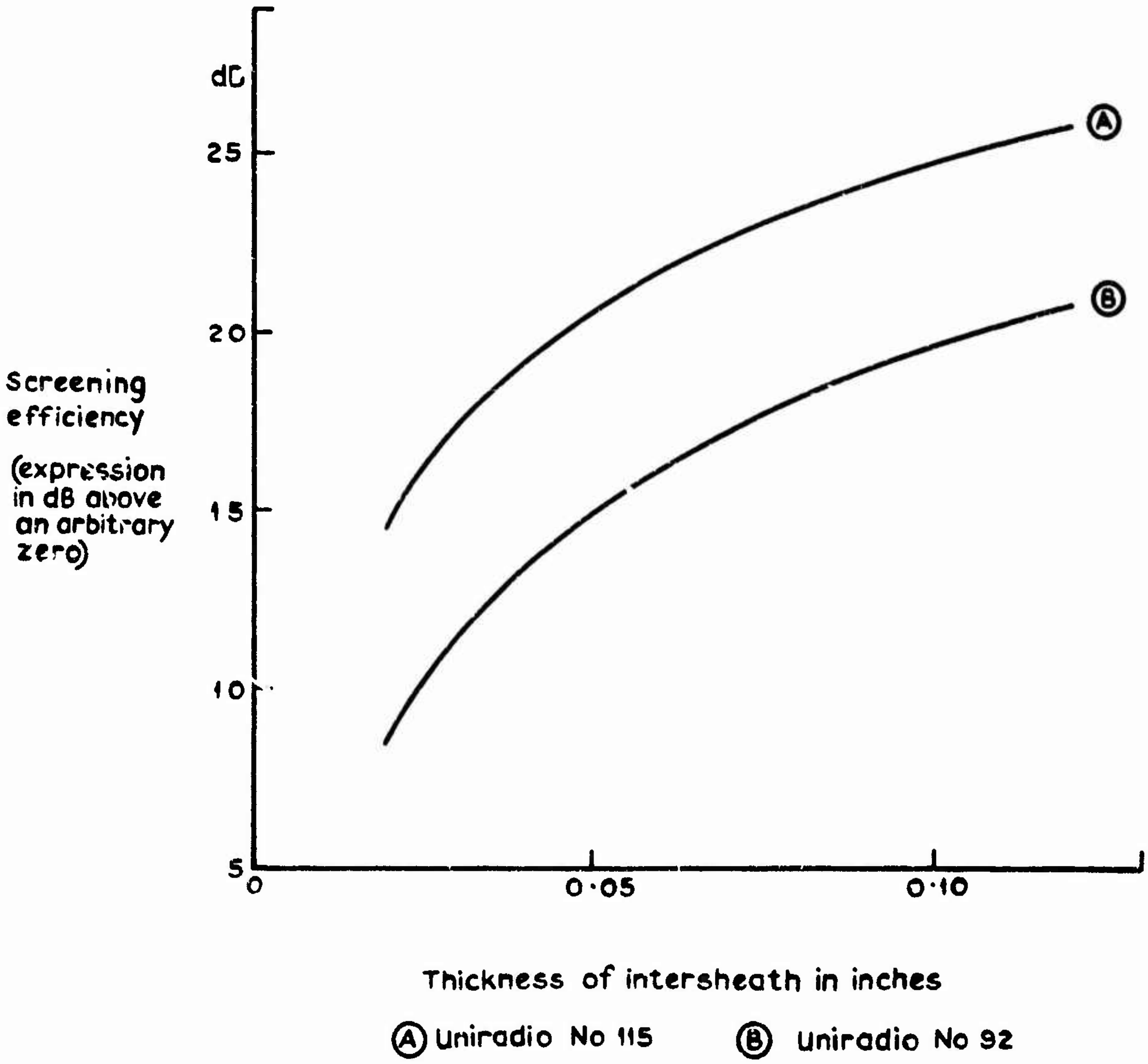
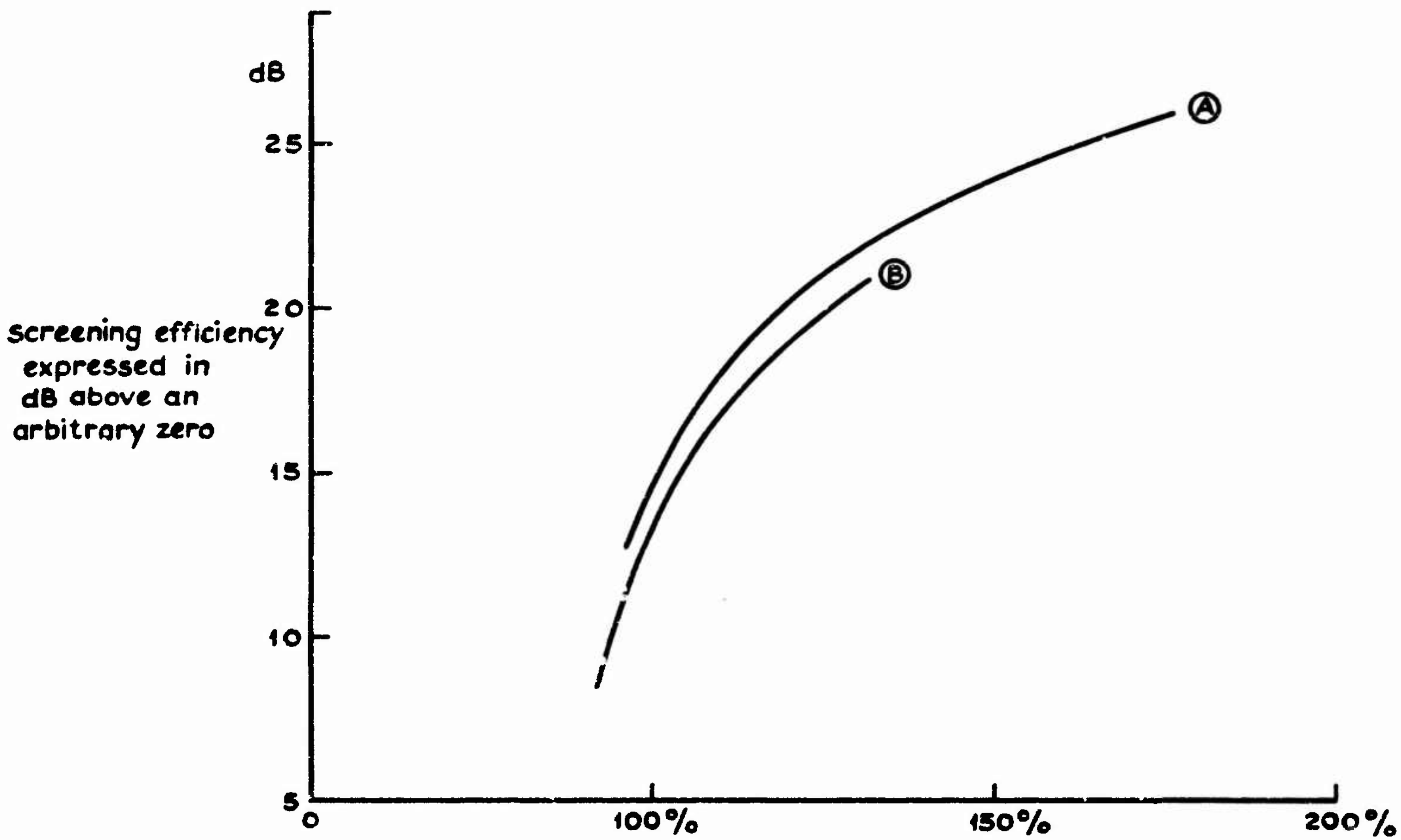


Fig.4 The screening efficiency as a function of intersheath thickness



Overall cable diameter as a percentage of that of the standard cable, (A) Uniradio No 115 (0·285 inch)
(B) Uniradio No 92 (0·540 inch)

Fig.5 The relationship between screening efficiency and overall diameter

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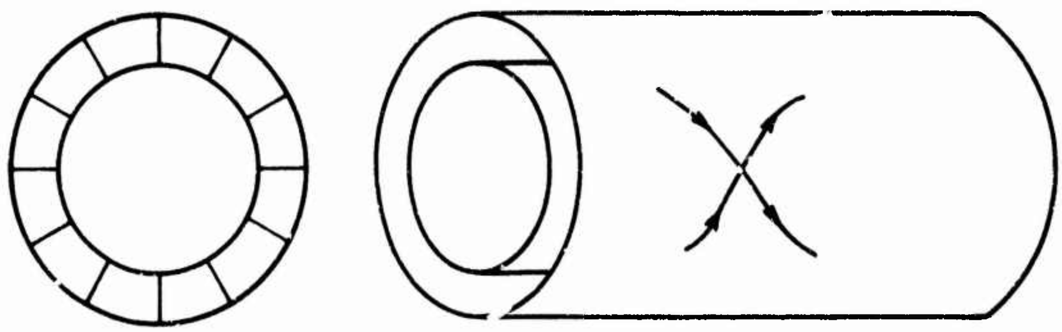

Concentric braids

The currents are uniformly distributed and two wires approaching a crossing carry equal currents

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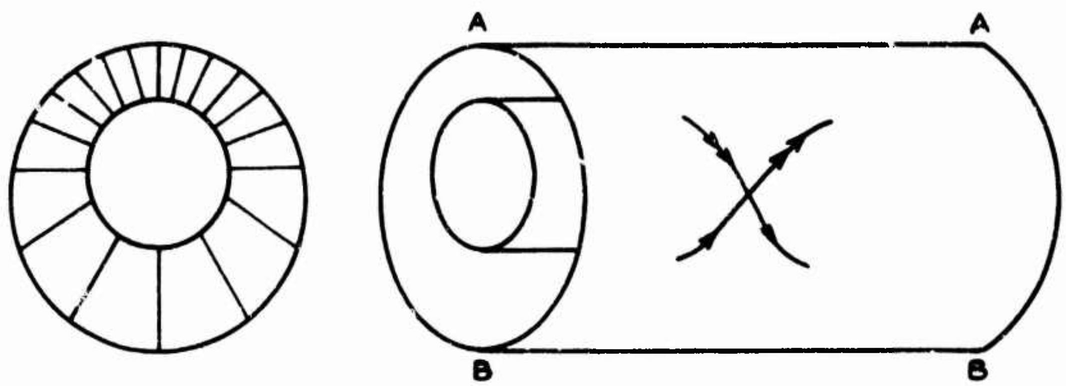

Excentric braids

The currents are concentrated in the region near the line A A where the braids are closest. At a braid wire crossing a wire coming from AA will bring a greater current than will the wire coming from BB. If the resultant current is to be parellel to the cable axis the excess current must be transferred to the wire leaving the crossing for AA

Fig. 6 Current distributions on concentric and excentric braids