Abstract – An accurate analysis of errors in the prediction of the crosstalk between braided coaxial cables were carried out in order to assess the accuracy of the commonly used prediction techniques. Since crosstalk is directly dependent on the magnitudes of the leakage parameters, which are usually measured the error margins in the measurement methods were examined first. The effect of such errors on crosstalk values were then investigated next. Such a first step analysis is useful in empirical determination of the statistical models in order to develop damage assessment of crosstalk on communication systems.

Key-Words: - EMC, Shielding, Communication Systems and Cables, Crosstalk, Transfer Impedance

1 Introduction
The advent of microelectronics has enabled many complex electronic equipment to be employed within a limited space. Braided coaxial cables are often used as interconnects in closely spaced bundles in such systems. Since such cables are not perfectly shielded electromagnetic coupling between them do occur causing crosstalk. A close attention to such crosstalk must be paid in order to attain optimum operation of the system. With the wider market penetration of the cellular radio operations the interference problems between cables and wireless systems, are becoming an important concern which must be properly addressed. This requires accuracy in the prediction of the leakage parameters on which the radiation and crosstalk predictions are based.

Braided coaxial cables have outer conductors made of criss-crossing belts of conductors to provide flexibility. Because of this the outer conductor contains a large number of diamond shaped holes and thus do not provide complete shielding against electromagnetic fields. A TEM wave generated inside the cable may couple to the exterior and any external field may couple to interior. At high frequencies the penetration into and leakage of electromagnetic waves from a braided coaxial cable is usually measured in terms of both transfer impedance \( Z_T \), which measures the magnetic leakage and the transfer admittance \( Y_T \), which measures the leakage of electric field. Transfer impedance at high frequencies is inductive where as the transfer admittance is purely capacitive. The theoretical models of crosstalk is quadratically related to the magnitude of these leakage parameters and any small error in the determination of them may cause large errors in the assessment of crosstalk [1-4]. The objective of the work presented in this paper is to develop an accurate first sight analysis procedure for error estimate caused my the margin of accuracy in the determination of leakage parameters. The error analysis of the leakage parameters is based on the experimentally determined values [3]. Two methods were considered and the differences between the measured values using either have been analysed. The effect of the error margin on the measured values were then projected onto theoretical models for crosstalk in order to calculate the differences between the estimated values. Mechanical distortions, twists on the cables and deformities caused on the braid structure during the measurements were experimentally accounted for and included in the error analysis for crosstalk. This study do not only throws light on the accuracy limits and performance details of the different cable designs but also the measurement techniques and hence it is a first step in establishing statistical methods for crosstalk which severely limits the performance of some communication schemes such as ISDL and VSDL etc.

2 Overview of theoretical models
Most widely used Theoretical models: -Tyni’s [5] and Vance’s [6]- used to calculate the leakage parameters are given in the Appendix. These models are accurate enough for over-braided cables (optical coverage greater than 95%) but not very accurate for optimised
cables (where, optical coverage is reduced to balance the braid and hole inductance) and under-braided leaky cables (where, optical coverage less than 60%). The transfer impedance model by Tyni proposes both hole and braid inductance in order to account for the linear rise at radio frequencies, whereas in the model proposed by Vance the braid inductance is not accounted for. Vance’s model is proved to be physically complete (i.e. all the magnetic coupling processes are accounted for) and it can provide accepted accuracy for over-braided cables. But the Vance’s model produces much poorer agreement, compared with Tyni’s model which is far more successful and hence employed in our studies. In some studies Vance’s and Tyni’s model have been combined but this didn’t create improved accuracy.

3 Measurement Techniques

Several techniques are offered for the measurements of the leakage parameters. However those techniques employing triple coaxial apparatus are the most accurate [1-3]. This uses a thick walled brass tube in a triaxial arrangement in order to collocate the coupled energy from the victim cable. Since the test sample is shielded entirely from the surrounding environment the measurements are far more accurate than other competing techniques [2-3]. IEC’s technique employed at lower frequencies [3]. The technique is illustrated in Fig.1, which employs short circuited outer line in order to suppress the electric field coupling (and to enhance the magnetic field coupling. This arrangement has the following disadvantages at high frequencies: (i) large measurement errors will result by ignoring electric field coupling, (ii) crosstalk responses at resonances caused by the short circuit cannot be accurately determined and (iii) the resistor bracket [1-3] used to house a matching transistor in the inner coaxial line causes large reflections. At high frequencies a more accurate yet practical technique is needed where such measurement inaccuracies in the existing IEC method can be eliminated. For this it is essential that the short circuit, in the outer coaxial, and the resistive bracket in the inner coaxial circuits are replaced with more stable terminations leading to minimal measurement errors. A practical way to achieve this is to develop a method whereby both circuits are strictly matched. This results in the so-called matched triaxial device which is solely designed for measurements at higher radio frequencies up to 3.0 GHz. Constructional details of the device are given in [2] in Fig.2, which also shows the actual device constructed and used to obtain the results. The middle section “A-B” (of length “L”) represents the “measurement area” where the physical coupling between the outer coaxial circuit and the cable sample under test takes place. In this area the velocities are matched using the same dielectric material as the cable sample. This particular prototype is designed to measure URM 43 size radio cables (mean diameter over inner dielectric is nominal 3.26 mm). Since the matched triaxial device is perfectly matched and accounts for both electric field and magnetic field couplings from the measurement sample it is more accurate than the lower frequency IEC’s device.

5 Results

Transfer impedance measurements on various cable designs with different braid structures in the frequency range from 100 kHz to 3.5 GHz have been carried out. Transfer admittance values were measured separately using a time domain method developed by Fowler [3] and included in the measurements employing the matched triaxial device before extracting the transfer impedance values [2]. The electric field coupling is ignored in the IEC’s device and because of this, based on the cable design, some discrepancy is expected between the two sets of results obtained from both measurement techniques[3]. The results from matched triaxial device are expected to be more accurate. Typical results are shown in Figs.3 for a URM43 size cable, together with the estimated values from Tyni’s model. The results up to 100 MHz are from from IEC device and those between 300 MHz-3GHz are from matched triaxial device. The results from IEC device are affected from the electric field couplings at the higher frequencies, which are not included in deriving the Z_T values from the crosstalk measurements. This is truly reflected in the results as the measured values deviate from linear rise expected. However the results from the matched triaxial device on the other hand do show linear behaviour. This shows that there is a significant error margin between the two device (about 10-15%) where the deviation from the accurate values exhibited by the IEC’d device is corrected by the more accurate matched triaxial device.

The error margin for the measurements of the leakage parameters is highly affected by the axial and longitudinal torsion which are unavoidable during the measurement set up [3-4]. It is impossible to account for these errors theoretically. The optimised braids are more affected than the over-braided cable due to their higher mechanical agility and sensitivity to external forces. This is clearly illustrated in Fig.4, where measurements were taken under several degrees of torsions applied. These values were then fed into our models to calculate the crosstalk. The results are shown in Fig.7 These results are fairly significant in that they clearly illustrate the effect of mechanical deformation on the field couplings and they can not be modelled theoretically. However a statistical approach can be used to estimate the error margin. The limits of accuracy of such model is quite important in practical applications as the certain communication schemes are
most affected by these variations in the field couplings. Tyni’s model is fairly successful in explaining these statistical variation in the measurements of $Z_T$. According to Tyni’s model the transfer impedance is comprised of two inductive components: hole inductance which is due to direct coupling of the field via the diamond shaped holes in the braid, whereas hole inductance is due the field linkage between the braid layers. Since this inductance is directly due to the magnetic flux trapped between the braid spindles it is directly related to the distance of the gap between these layers. The torsion effects the height of this gap resulting in the variation of the values for the braid inductance values. The effect is not homogeneous as for the certain sections of the braid the height between the spindles may increase whereas for others it may decrease. So the effect is random in nature and can not be analytically calculated. This necessitates a statistical approach.

4 Conclusions
An error analysis to explain the discrepancy for the crosstalk calculations and measurements were attempted in this paper. It is seen that most problematical areas are the measurement of leakage parameters which are effected by the torsions and hence deformations in the braid structure. Such effects have a direct influence on the crosstalk analysis which was clearly demonstrated in this study.

5. Appendix— Tyni’s model
The widely used theoretical model for transfer impedance at radio frequencies is due to Tyni [6,7,12]. According to this model $Z_T$ is assumed be inductive at radio frequencies which is represented as $Z_T \equiv j \omega (M_b + \text{mM}_h)$; where the inductive rise is made of braid inductance which accounts for the magnetic flux coupling between the braid spindles and hole inductance. The hole inductance is responsible for the direct linkage of the magnetic field via the diamond shaped holes in the braid to outside and vice-versa. For the per-unit-length braid inductance Tyni suggested

$$M_b = \frac{\mu_0 h}{4\pi D_m} \left(1 - \tan \theta^2\right)$$

(11)

For the hole inductance Tyni gave

$$M_h = \frac{\mu_0 2N}{\pi \cos \theta} \left(\frac{b}{\pi D_m}\right)^2$$

(12)

where $h$ is the mean distance between the braid spindles, $D_m$ is diameter of the cable over braid, $\theta$ is the braid angle, $N$ is the number of spindles, and $b$ is the braid wire diameter (see Table I). It is clear that for braid angles less than 45° hole and braid inductance oppose each other. Thus if the braid inductance is dominant this will result in the polarity change of $Z_T$. Tyni’s model gives accurate predictions for the over-braided cables but its

References:

Fig.1 IEC’s Triaxial device

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Fig. 2 Symmetrical half section of the constructed matched triaxial device with design dimensions.

Fig. 3 Measured and theoretical values for Transfer Impedance.

Fig. 4 Measured Transfer impedance under longitudinal twist.

Fig. 5 Measured crosstalk under the torsion as in Fig. 4.