Selection Criteria of Filtered RJ Modular Jacks/Connectors

An effective solution to low-level surges is to filter at the interconnect point where RJ jacks/plugs are used.

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INTRODUCTION

Since the development of the RJ jack/plug modular intercon nect system by AT&T in 1974/1975 for residential applications, the sheer volume of these devices has swelled to surpass all other types of connectors combined. Due to their small size, high reliability, low cost, and ease of use, applications have expanded beyond basic residential telephone use to include modem connections, intra-office workstation interconnects, and LAN transceivers to twisted pair wiring. A common example of the last application is Ethernet (10BASE T). At the other extreme, these devices have been adapted to connect low-current dc power sources to various loads. The standard method of connection uses twisted pair wiring for economy and in many instances is already installed and available for use. Twisted pair wiring acts both as an emitter and a receptor for line-to-ground (L-G) noise signals and low-level surges. L-G noise present in some high density modern offices, and increasing in some instances, can create electronic havoc in the operation of L-G noise-sensitive equipment.

Even equipment emissions within allowable FCC limits (defined in the FCC Rules and Regulations, Part 15 Subpart J) have interference potential. The remedial use of valuable PCB space to contain filter elements becomes increasingly less viable due to shrinking equipment size. Higher data rates (e.g., 100BASE T) and associated harmonics are on the horizon and promise to challenge us all.

To suppress unwanted noise and low-level surges, an effective solution is to filter at the interconnect point where RJ jacks/plugs are used. Filtering can be passive and may consist of inductors (ferrite cores) and/or capacitors. Appreciable attenuation from 30 MHz to 1000 MHz can be demonstrated and, depending on the application, there will be minimal signal disturbance. Analogous to bulkhead mounted power-line filtering, this "last chance" signal line filtering at the PCB perimeter (or "first chance" for incoming noise) is especially suitable for retrofitting situations, when PCB discrete filter space allocation is nonexistent. This retrofitting is especially beneficial in the common situation where a noise problem is discovered during full system testing, usually near the production startup date. A speedy solution which has minimal effect on other parts is needed.

TYPES OF MEANINGFUL TESTS

To avoid or to solve data line noise emission or susceptibility problems using filtered jacks, predictive methods to determine performance are certainly worthwhile goals. Experience has taught power-line filter users that, although far from perfect, rough estimates as to filter component circuitry and values are more time-saving than "shots-in-the-dark" in solving noise problems. This estimate of component values and performance can be considered using the following three methods of evaluation: GTEM cells, impedance, and insertion loss.

GTEM CELLS

In the EMI world, the use of GTEM (gigahertz transverse electromagnetic) cells has gained a substantial following. Lack of reflected waves, repeatability, conditional FCC acceptability, and laboratory compatibility are the main virtues. On the downside are high cost (for equipment not generally in high use) and limited equipment-under-test physical size.

Testing is functional, and can consist of a well-shielded noise generator or equipment whose circuitry is similar to the final version, placed inside the GTEM cell. Various output jacks, terminated in an unshielded wire pair, are measured for wire pair radiation, and compared for output level.

IMPEDANCE

Most filtered jacks utilize ferrites for the inductive, or more correctly, the series element. The high resistivity types exhibit increasing resistance with increasing frequency; ferrite manufacturers characterize by impedance at a specified frequency. Although this permits efficient component testing, it doesn't mesh with standard filter/EMI terminology and test equipment readout. Also, impedance doesn't address other filter elements (shunts).

INSERTION LOSS (IL)

Insertion loss, usually expressed in a 50-ohm environment, is the familiar connector, cable, and test equipment standard. Although insertion loss and equipment performance do not always correlate well, estimates of required attenuation and insertion loss are still very helpful in achieving the desired emissions level. Magnitudes and locations of peaks and valleys in insertion loss-versus-frequency plots, as well as the frequency range of high/low insertion loss can aid in the selection process. Since the characteristic impedance of unshielded twisted pair data lines is a known 100 ohms, prediction

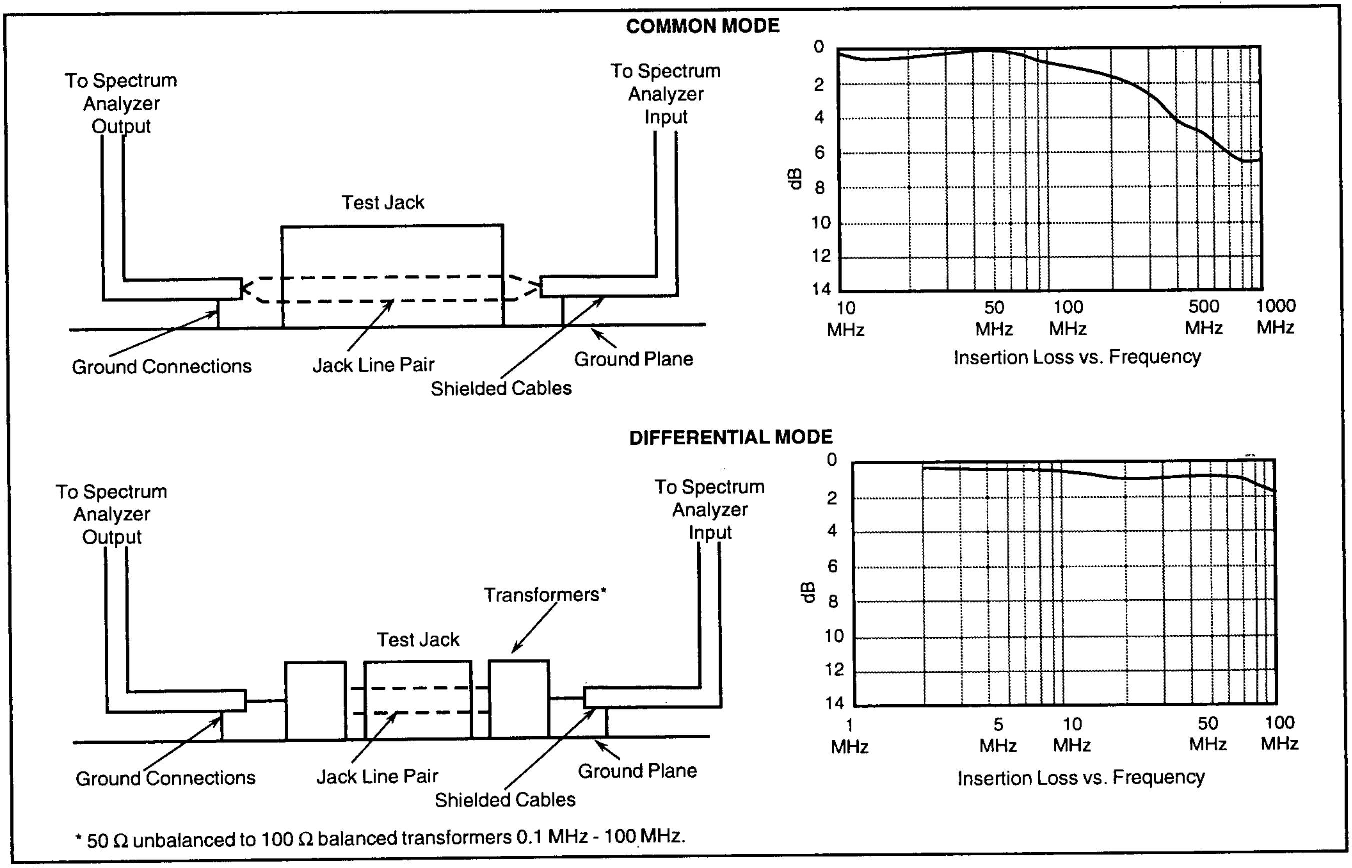

Figure 1. *RJ Jack Insertion Loss Methods. Note: Insertion loss measurements of filtered jacks used an unfiltered jack as a reference.*

should be more realizable than with power-line filters, since power lines are difficult to quantify. For these reasons, the insertion loss method will be the focus of this discussion.

The insertion loss measurements discussed here were all performed using a custom test fixture, HP Model 8568A spectrum analyzer, and a shielded room. The test fixture consisted of a small rectangular metal enclosure with a vertical center partition for mounting various filtered jacks. Shielded test cables were brought through the enclosure and terminated with very small leads.

Both the common and differential mode (CM and DM) setups are illustrated in Figure 1. The CM configuration is a direct 50 ohm, which agrees with the generally accepted 50 ohms from each line to ground. The DM setup matches twisted pair 100 ohm characteristic Z, via 2 to 1 balanced to unbalanced transformers.

To demonstrate the effectiveness of the test setups, the graphs in Figure 1 illustrate the effects of short unshielded test wires in these setups – note the less than 2-dB loss up to 100 MHz. This is attributed to transformer and unshielded mismatch losses, and is considered acceptable.

The insertion loss data generated used an unfiltered jack as a reference (0 dB) in order for users to easily compare the effects of added filtering, with all other aspects constant.

PERFORMANCE COMPARISONS

Performance levels of three categories of filtering will be compared:

- Ferrite blocks (1 piece with multiple holes) or individual ferrite sleeves
- Capacitors only (82 and 820 pF)
- Combinations of ferrites and capacitors

FERRITES ONLY

A comparison of low permeability (LO μ) and medium permeability (MED μ) blocks revealed a slightly broader CM response and lower DM loss associated with the LO μ materials (Figures 2A and 2B). The lower DM losses may be especially significant for data transmission rates at the standard 10 megabyte rate: 3 dB versus 0.5 dB. Ferrite sleeves yielded a flat 2 dB CM insertion loss from 30 to 800 MHz (Figure 2C). The sleeves should only be considered where minimum crosstalk is desired, as some sacrifice in attenuation occurs as seen by comparing Figures 2B and 2C.

CAPACITORS ONLY

Immediately apparent in direct comparison with previous ferrite-only levels is a magnitude in CM improvement (note the difference in vertical axis scales). Above resonance, the CM response is a nearly flat 25 dB out to 1

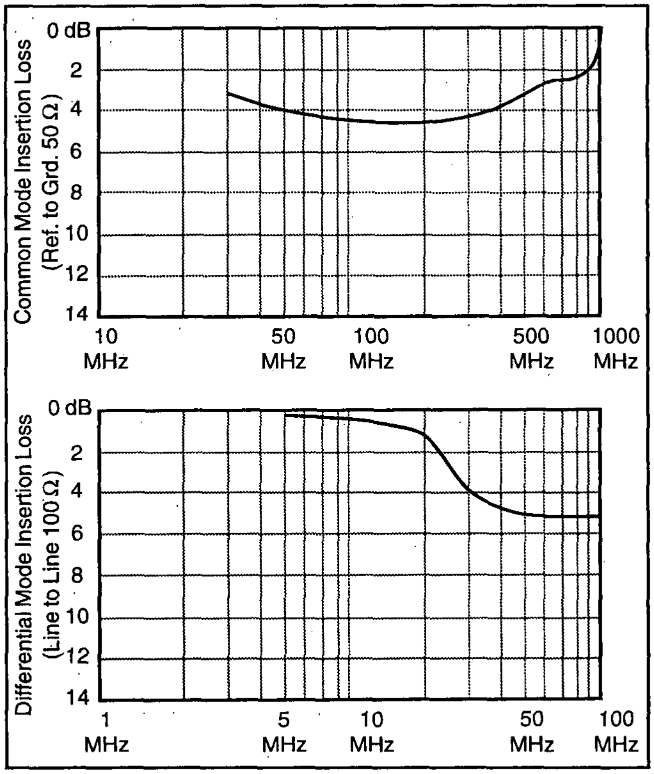

Figure 2A. Insertion Loss with LO-µ Ferrite Block Only (125 µ).

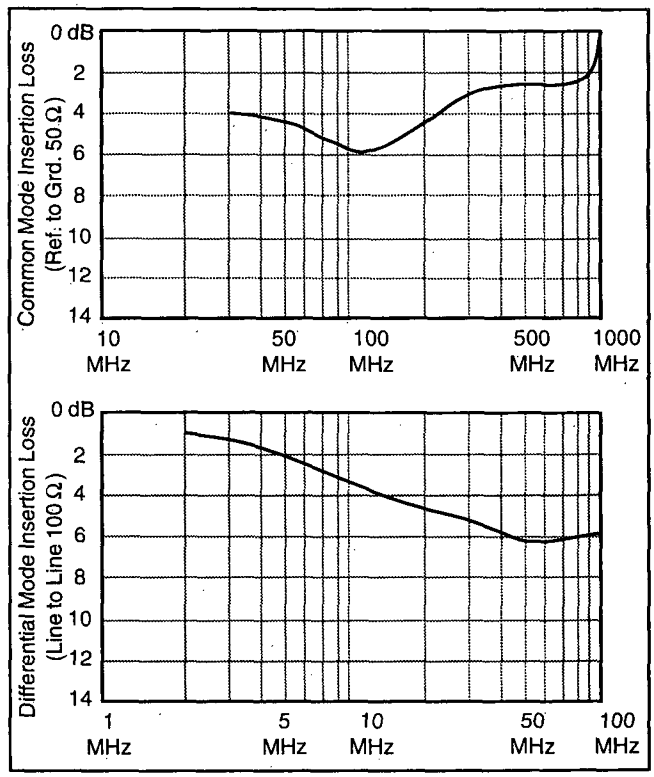

Figure 2B. Insertion Loss with Standard Ferrite Block Only (850 µ).

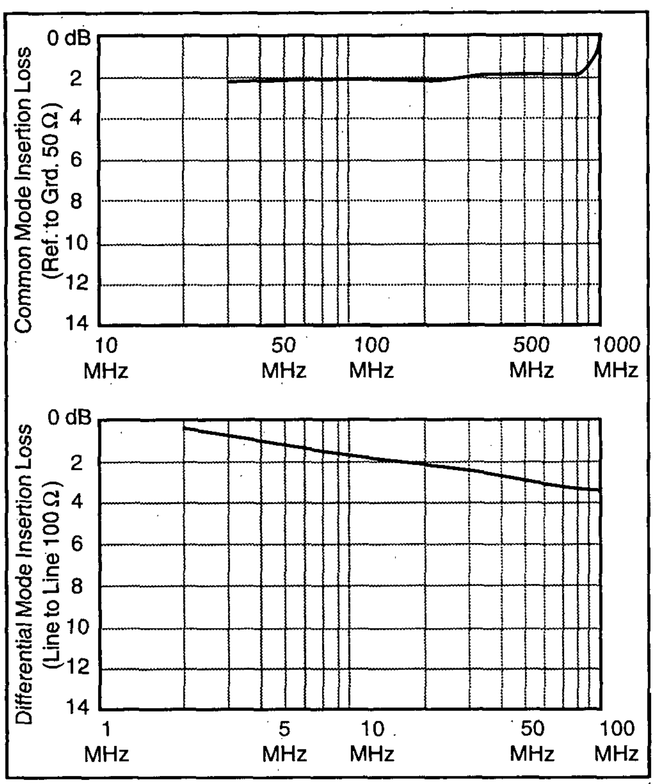

Figure 2C. Insertion Loss with Standard Ferrite Sleeves Only (850 µ).

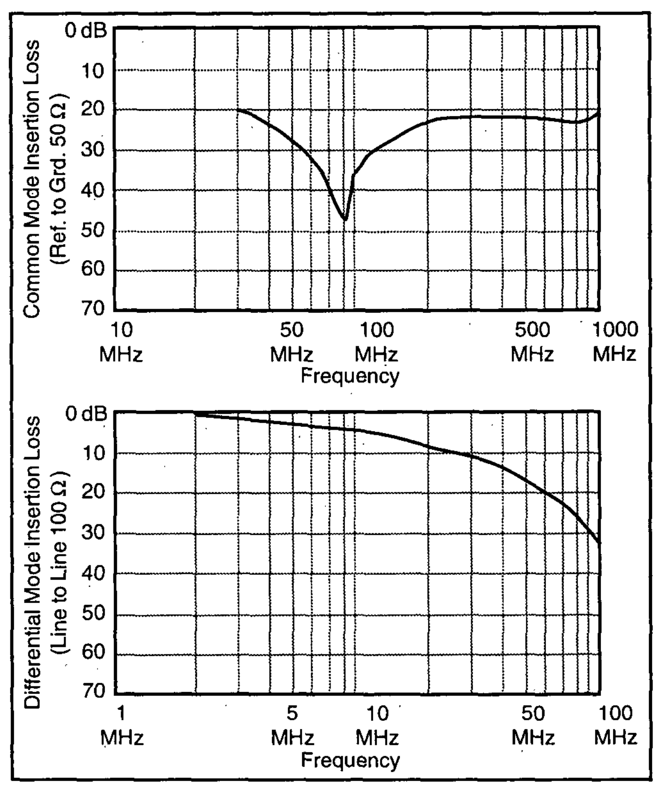

Figure 3A. Insertion Loss with Capacitors Only (820 pF) — No Ferrites.

GHz (Figure 3A). If the predominant system noise is above 200 MHz, the best choice would be the 82-pF version, as this would minimize capacitive effects on data wave shape and twisted pair characteristics. The two grounded 82-pF capacitors in series across each line pair, or 41 pF, is insignificant compared to the category 3 mutual capacitance limit of 20,000 pF per 1000 feet, as specified in TSB-36 of EIA/TIA related to twisted pair

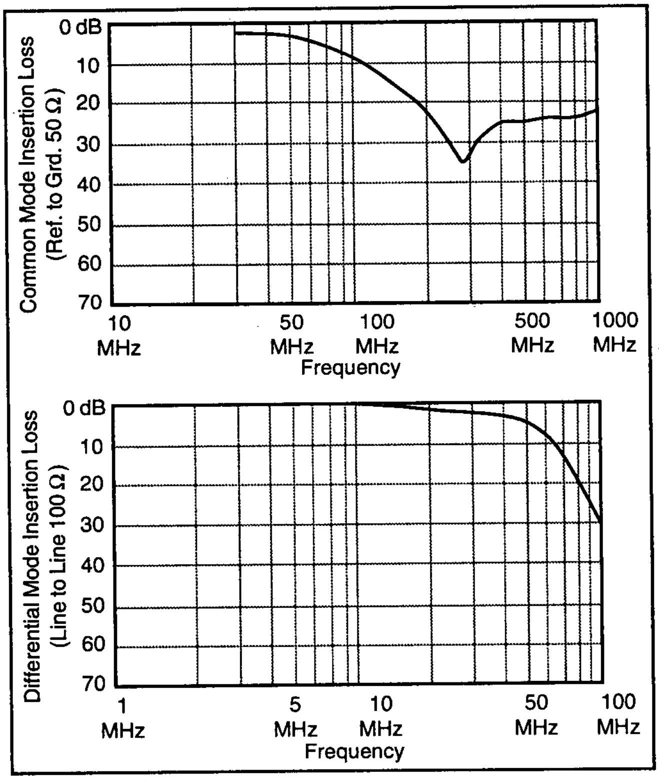

Figure 3B. *Insertion Loss with Capacitors Only (82 pF)—No Ferrites.*

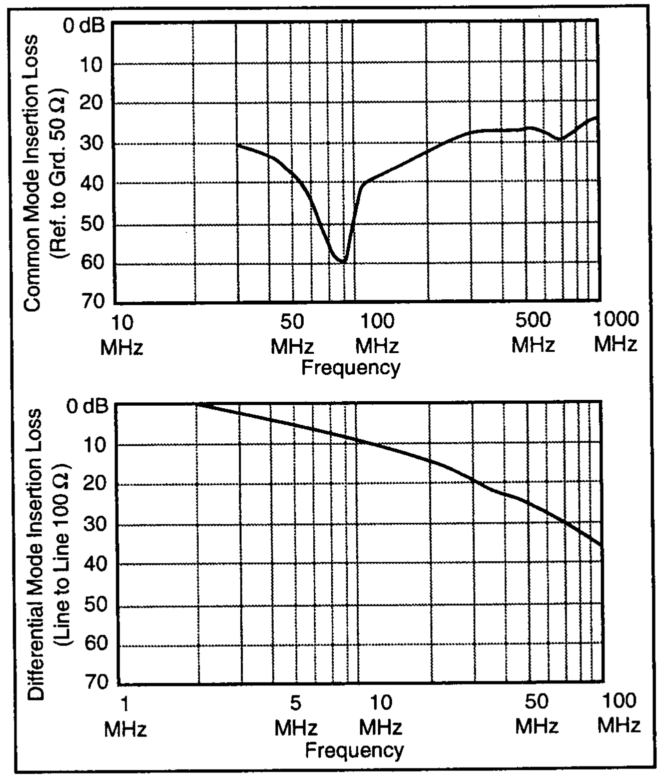

Figure 4A. *Insertion Loss with Standard Ferrite Block (850 µ) Plus Capacitors (820 pF).*

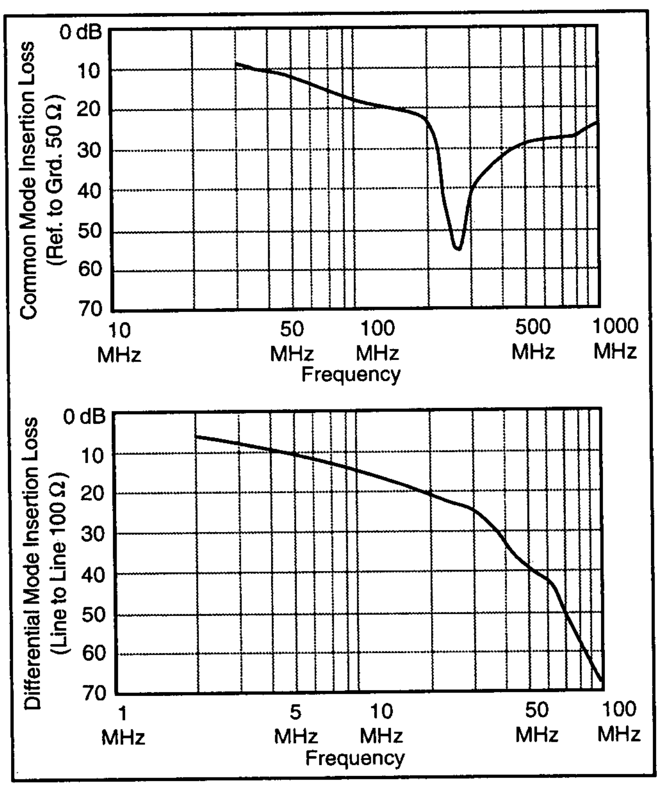

Figure 4B. *Insertion Loss with Standard Ferrite Sleeves (850 µ) Plus Capacitors (820 pF).*

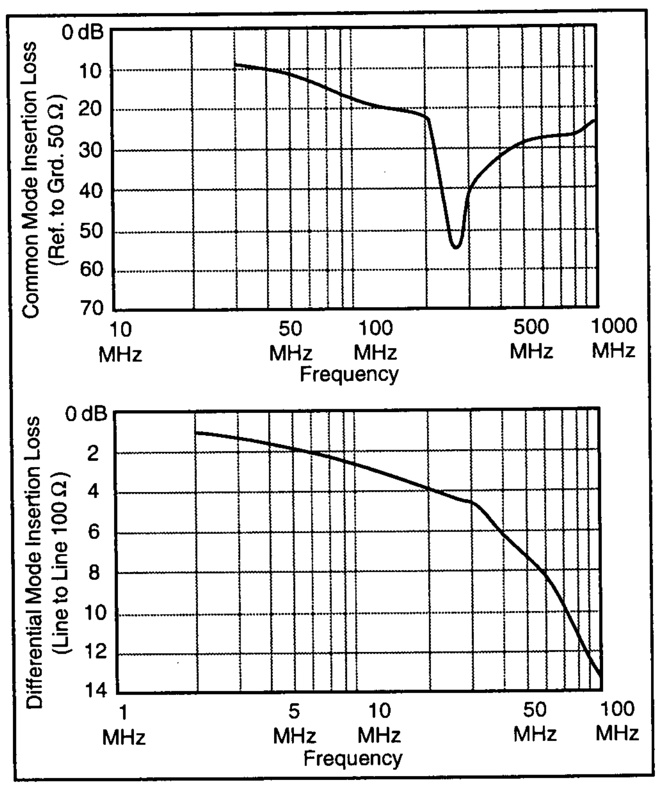

Figure 5A. *Insertion Loss with Standard Ferrite Blocks(850 µ) Plus Capacitors (82 pF).*

cables. Also, DM loss below 50 MHz is inconsequential for the 82-pF model (Figure 3B).

If system noise is concentrated at or near either resonance point (90 or 270 MHz), that capacitor type should be selected, as this represents internal capacitor attributes, and its resonant frequency location may be affected by external ground inductance.

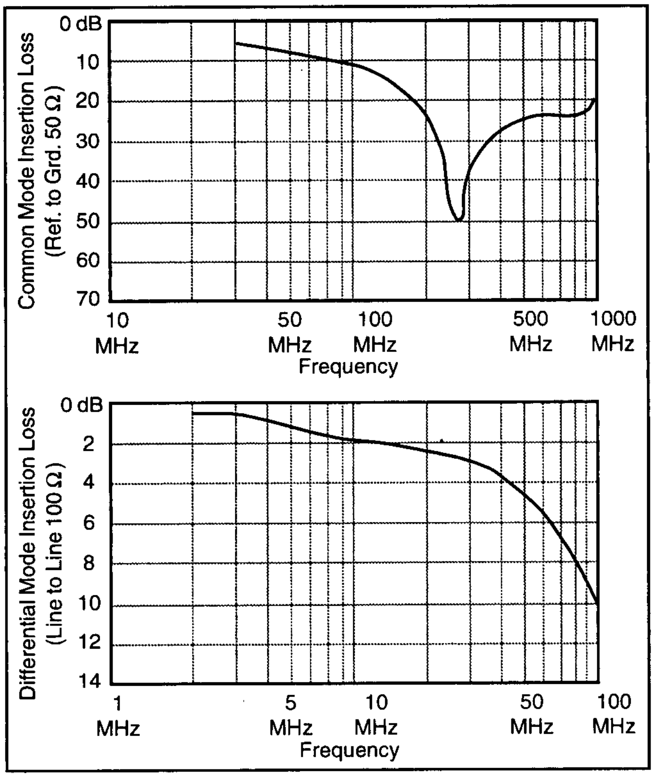

Figure 5B. *Insertion Loss with Standard Ferrite Sleeves (850 μ) Plus Capacitors (82 pF).*

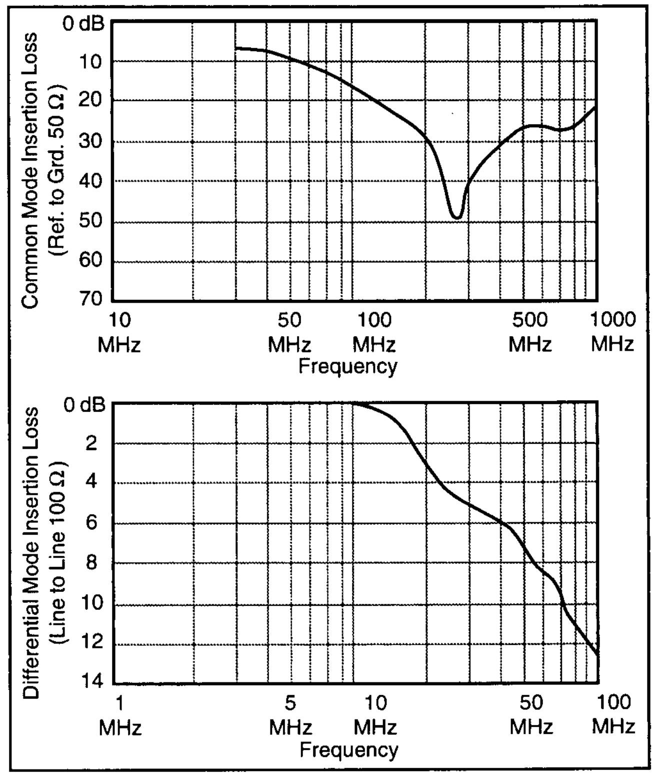

Figure 6. *Insertion Loss with LO-μ Ferrite (125 μ) Block Plus Capacitor (82 pF).*

	820- pF Capacitors		82- pF Capacitors	
	Ferrite Block	Ferrite Sleeve	Ferrite Block	Ferrite Sleeve
Minimum Crosstalk		X		X
High Frequency Resonance			X	X
Max. Low Frequency CM IL	X			
Max. High Frequency CM IL			X	
Minimum 10 MHz DM Loss*				X

* or LO μ block for even lower loss

Table 1. *Ferrite/Capacitor Combination Attribute Table.*

FERRITES AND CAPACITORS

Figures 4A and 4B illustrate the effects of adding ferrite blocks or sleeves (MED μ), respectively, to the 820-pF capacitive models; 30 to 200 MHz CM insertion loss improvement is especially noteworthy (8 to 15 dB), while a 3-dB or 4-dB increase occurs beyond that for the ferrite block. Improvement associated with the sleeve model is roughly one-half that of the blocks.

Figures 5A and 5B explain 82-pF type enhancements, with the inclusion of the same type of ferrite blocks/sleeves. The block CM increases 5 to10 dB from 30 to 500 MHz, but only 2 dB (except for the resonance area) with sleeves. For DM comparisons, note the vertical axis scale change between 82 and 820 pF. If absolute minimum DM losses are desired with very little high frequency CM sacrifice, refer to Figure 6. The LO μ ferrite block with 82-pF capacitors exhibits near-zero DM losses and about 25 dB CM insertion loss from 150 to 900 MHz.

In order to assist users in model selection for the various ferrite/ capacitor combination styles, Table 1 may be useful.

CONCLUSION

It is hoped that this test method background, various style attributes, and selection criteria will aid circuit designers, network analysts, and EMI engineers in selecting the particular model to best suit the application. Other ferrite materials (HI μ) were investigated but no benefits were discovered; in fact, DM losses generally increased, while CM insertion loss decreased.

DON TALEND, *a native of Chicago, IL, received his BSEE degree from the University of Illinois, and has 33 years of experience in Component Engineering - the last seven in telecommunications. He received a patent for Corcom's filtered modular jack. (708) 680-7400.*