A New Technique for Measuring the Shielding Effectiveness of Interconnection in Shielding Technologies: Application to Cellular Phone Gaskets for the Housing

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Abstract: A technique for measuring the shielding effectiveness of an interconnection method, such as a gasket system, and an accompanying figure of merit using shielded magnetic probes have been developed. The technique and figure of merit have been applied to a cellular telephone gasket system in the frequency range of 50-6000 MHz. The frequency range can be extended to 8500 MHz with the same probe design. Other shielding interconnection systems in common use in the industry can be studied using these custom designed shielded magnetic probes.

Introduction

There is a critical need in the electromagnetic compatibility industry to develop methods for measuring the shielding effectiveness, SE, of gaskets in electronic equipment in a simple and reproducible manner. [1-4]

A custom designed near field magnetic probe, hereafter called probe, has been fitted to a cellular phone housing and used to measure the shielding effectiveness of the gaskets in the housing. The basic measurement system uses one probe as a transmitter and another probe of the same design as a receiver. The gasket system for the housing is placed between the transmitting and receiving probes and the insertion loss is measured. This paper will report on the measurement procedure and the results of the study.

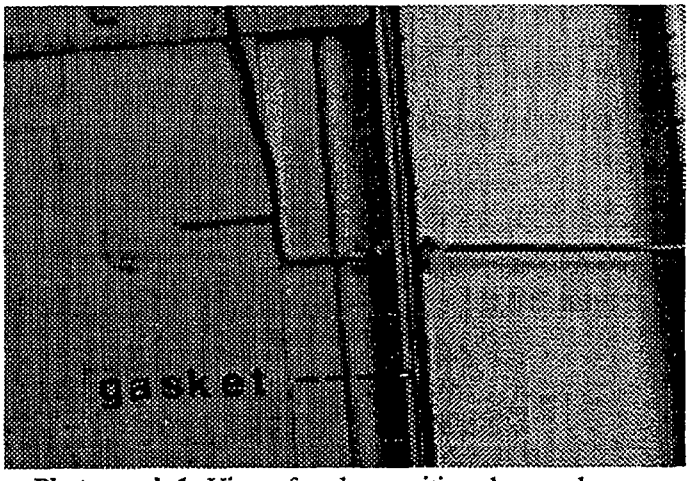
Experimental Procedure

Phone Casing Samples

The samples of the phone being tested were generated as follows: (1) at the step where the printed circuit board, PCB, is put into the housing, shims were used to replace the PCB so space would be allowed to insert the probes. (2) the appropriate pressure was applied by the casing screws to the gasket.

Measurement Procedure

Measurement of the shielding effectiveness of the gasket involves placing a 0.1 inch diameter probe, used as a transmitter, adjacent to the outside of the slit/groove/gasket, SGG, in the housing. An additional 0.1 inch diameter probe, used as the receiver, is custom designed to fit through the key holes in the housing. It is placed immediately adjacent to the SGG and opposite to the transmitter probe on the other side. The arrangement is shown in Photograph 1. The final position of the probes is determined by maximizing the coupled signal strength.



Photograph 1: View of probes positioned on enclosure.

The probe on the outside is used as the transmitter in order to minimize the effects of cavity resonance from the inner compartments of the phone. Photograph 2 shows a top view of the cellular phone. Positions 1, 3, 6, 8 are indicated in Photograph 3. Positions 6s and 9s are the wall sites. These are positions on the housing where there are no holes and the shielding material is representative, and are also visible in Photograph 2.

The probes used are also shown in Photograph 3. The probe that is bent 90 degrees was placed in position 1 and data was taken on an HP8720C network analyzer. The housing was then removed and the coupling measured over the frequency range of 50 MHz to 6000 MHz at the same distance as when the housing was present. This establishes the baseline for calculating the loss of the housing and gasket.

This process was repeated 3 times with and without the housing by repositioning both probes each time a measurement was made. The next positions (3, 6, and 8) were also measured in the same way. The data was automatically transferred to ASCII files for data analysis.[5]

Data Analysis Procedure

The sequence for data analysis is as follows: (a) measurements were made with and without the housing, as described earlier, and the difference between these measurements was calculated, see Figure 1; (b) the data

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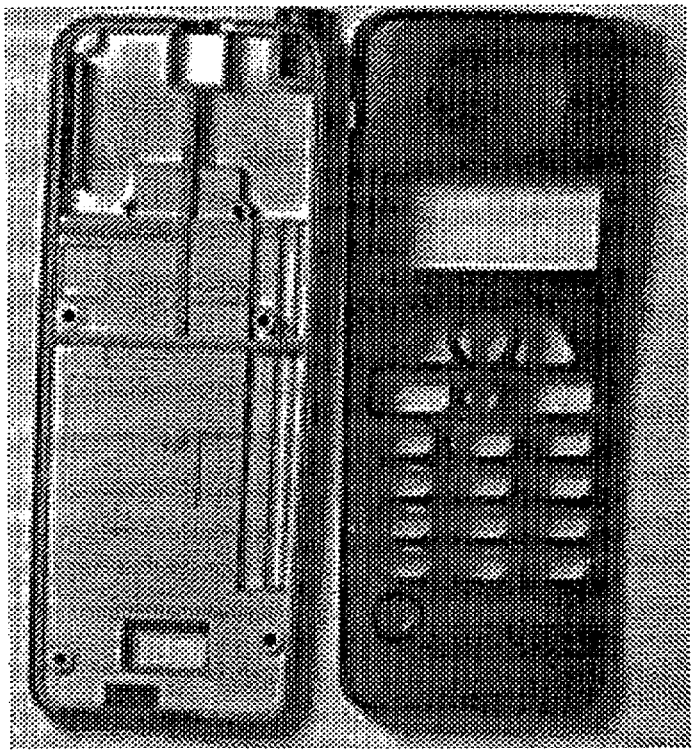
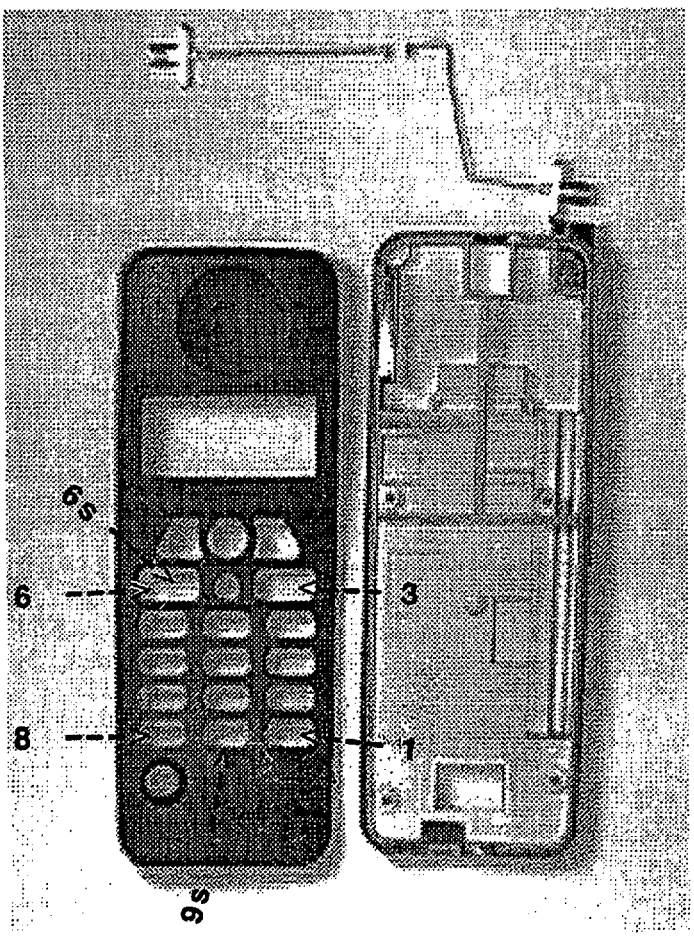


Photograph 2: Top view of cellular phone.



Photograph 3: View showing various points on the phone.

between 823 and 6000 MHz was plotted as in Figure 2; (c) a qnorm plot with a robust linear regression fit for the data from 823 to 6000 MHz was made as shown in Figure 3; and finally (d) a notched boxplot, as shown in Figure 4, was made.

The interpretation of the notched boxplot is as follows. The top line includes 95% of the samples. Those that have a value less than the line. The bottom line includes 5% of the samples that have a value less than that line. 75% of the samples have a value less than the top of the box and 25% of the samples have a value less than the bottom of the box.

The dashed line and notch near the middle of the box have special statistical signifance. The dashed line is the median and the notch represents an interval estimate, with a 95% confidence level, of the median. When two notched box plots are superimposed by shifting them horizontally and the notches overlap, then it cannot be said, with a 95% confidence factor, that the medians do not come from the same distribution.[5,6] The double negative in the last sentence is not precisely the same as the positive. At the risk of oversimplification, the double negative means that the medians may come from the same distribution. One cannot say that they do not.

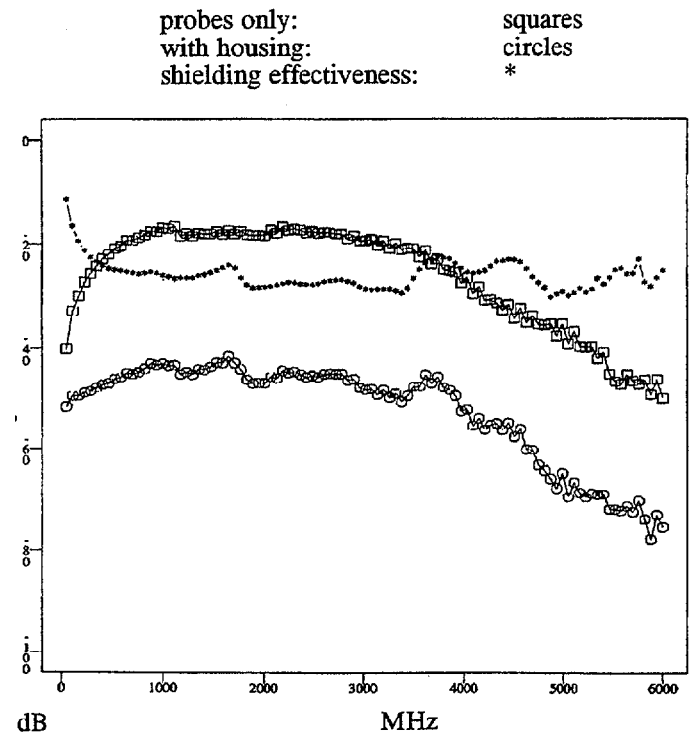


Figure 1. Coupling strength of probes for SGG Site 1 (dB from 50 to 6000 MHz)

The analysis presented in Figures 1 through 4 refers to the SGG site 1. All of the data sets of the remaining sites were treated in the same manner. The qnorm plot is a visual method of determining whether a data set is normally distributed. If the robust linear regression best represents the data, then the data set is determined to have a normal distribution.

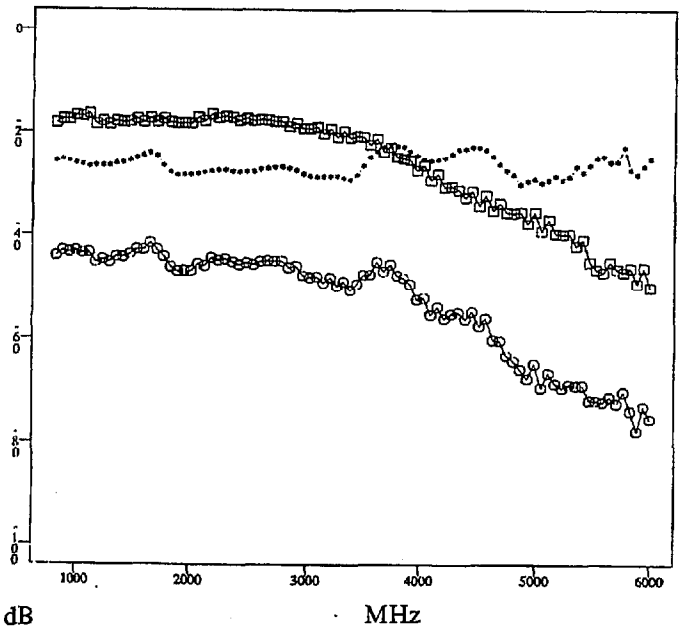


Figure 2. Coupling strength of probes for SGG Site 1 (dB from 823 to 6000 MHz)

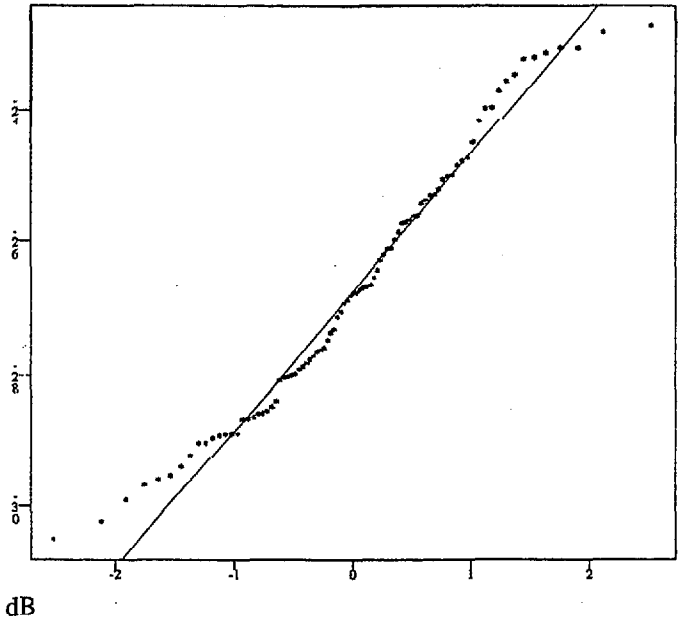


Figure 3. Visual test (quantile normal) for SSG site 1

Figure 5 shows a comparison of all 6 sites for shielding effectiveness. Figure 6 shows a comparison of notched boxplots for all 6 sites. Notches for data sets 3 and 6 overlap (when shifted horizontally). This means that it cannot be said that the medians do not come from the same distribution, with a 95% confidence factor. Whereas data sets 1 and 8 are quite different from each other as are data sets 1 and 6 as well.

The mean and standard deviation are calculated for each data set and are shown in Table 1. Site 6 shown in Figure 7, was the only data set that did not show a normal distribution.[6] The mean of all 12 data sets for the SGG and 6 data sets for the wall was calculated. The difference between the means for the SGG and the wall is also shown in Table 1.

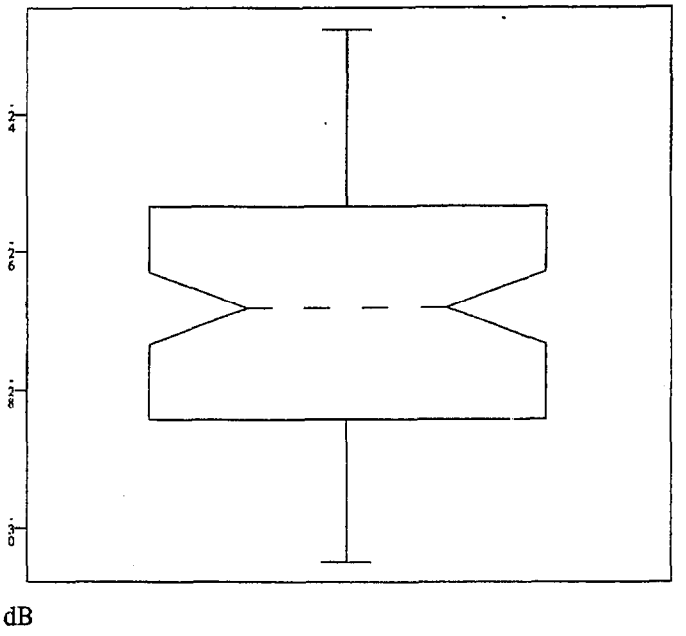


Figure 4. Notched boxplot for SGG site 1

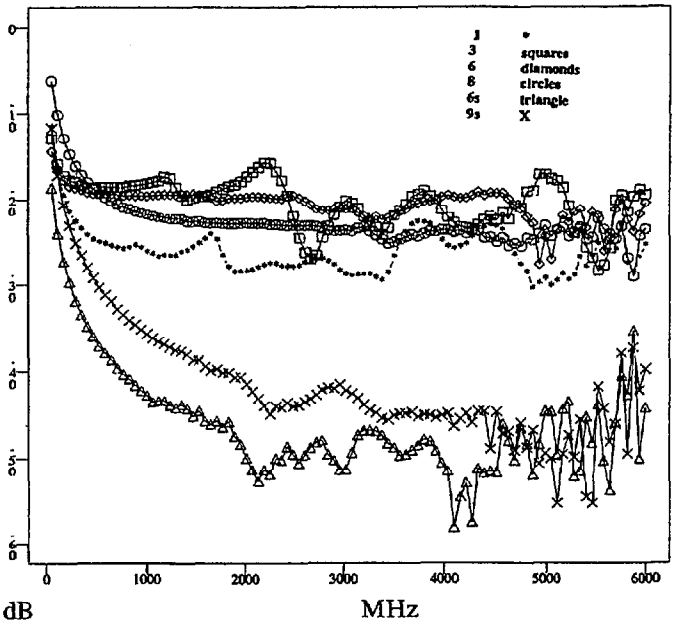
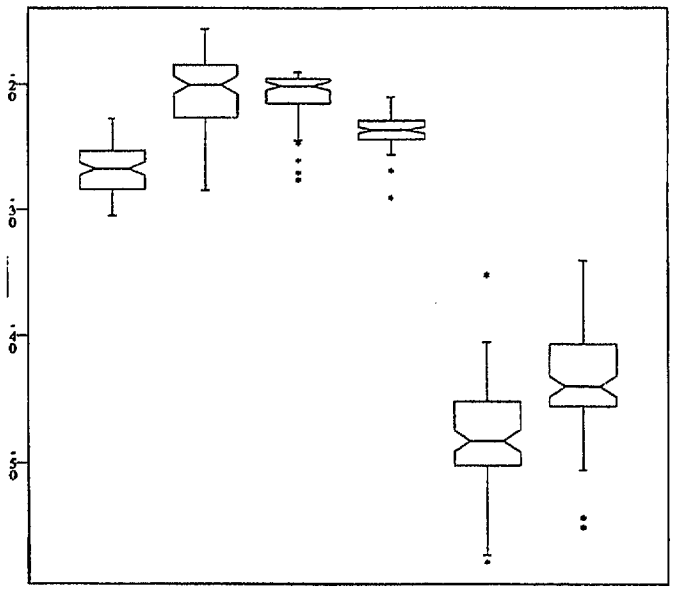
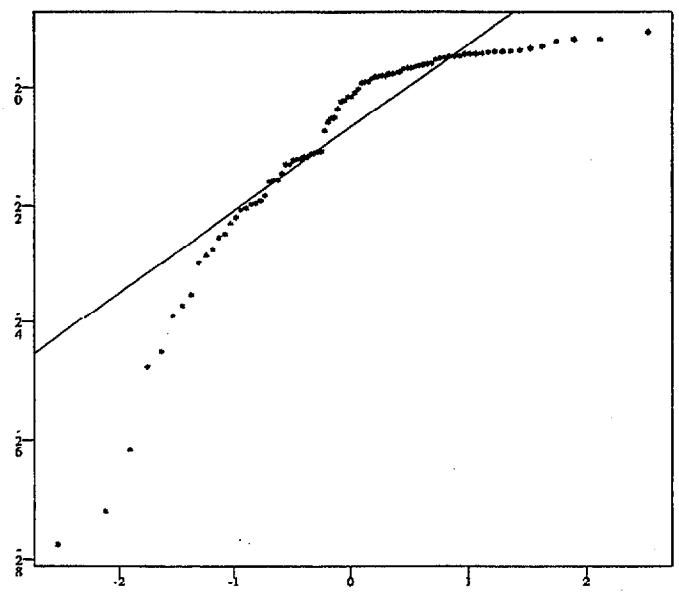


Figure 5. Comparison of Shielding Effectiveness for SGG Sites 1, 3, 6, 8, and wall sites 6s and 9s (dB from 50 to 6000 MHz)



dB

Figure 6. Boxplot comparison of shielding effectiveness for SGG sites 1, 3, 6, 8, and wall sites 6s and 9s (left to right respectively)



dB

Figure 7. Visual test (quantile normal) for SGG site 1

Discussion of Results

The periodic variation of shielding effectiveness, shown in Figure 5, of SGG sites 1 and 3 is probably due to cavity resonance.[7] This is not seen in SGG sites 6 and 8 and wall sites 6s and 9s because the section of the phone housing has a lesser number of cavities. See Photograph 2.

The difference between the SGG and wall sites is a measure of the leakage of electromagnetic energy due to the housing wall opening. This leakage is a direct function of how effectively the housing is closed after assembling the phone. The difference offers a figure of merit for comparison of interconnection technologies such as SGG used in this phone. The value arrived at for this example is -22.81 dB.

Using this figure of merit for interconnection shielding effectiveness, a complete process for decision making can be constructed. It could include other attributes such as availability, reliability, speed of development/lead time, cost, weight, ease of assembly/disassembly, environmental impact, and thermal management.

	Summary of Shielding Effectiveness			
	Slit/Gasket		Wall	
Sample	Mean	Standard Deviation	Mean	Standard Deviation
1	-26.73	2.22		
3	-20.76	2.94		
6	-20.56	0.78		
8	-23.70	0.18		
6s			-47.90	3.72
9s			-43.59	4.42
Total	-22.94	2.91	-45.75	3.05

Shielding effectiveness = -45.75 + 22.94 = -22.81

Table 1. Summary of Shielding Effectiveness

Summary

A technique for measuring the shielding effectiveness of an interconnection method, such as a gasket system with screws, has been developed using custom designed shielded magnetic probes. This technique has been applied to the design of a cellular phone housing in the frequency range of 50 to 6000 MHz. A figure of merit for comparison of various gasket materials and interconnections has also been developed.

Acknowledgements

We wish to thank Chauncey Herring, Jr. of AT&T Bell Labs for making good and reliable measurements as well as Ted J. Sikourski, also of AT&T Bell Labs, for his unmatched skills in the fabrication of these probes. The contributions of these two people made this development effort possible.

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