ECONOMY OF NEAR FIELD ANTENNA MEASUREMENTS

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BACKGROUND

Near field antenna measurements have long been of interest to the antenna community and of particular interest to those in the design and measurement of antennas. Efforts in this area using analog computers for data reduction were already under way in the late 1950's. These applications were limited, primarily due to the limitations of the analog computer. Two planar near field probe positioners were built by Scientific-Atlanta during this period and delivered; one to Martin Denver and one to the Georgia Institute of Technology. These units were used for development on planar near field measurements. The unit at Martin Denver was also used by the Bureau of Standards. Experimental work at Georgia Tech led to Dr. Joy's thesis on spacial sampling and filtering.[1] This work on sampling was particularly important because it gave an understanding of the required data density for meaningful transformation by digital computer. Numerical integration is a time and core intensive process and it was the utilization of the Fast Fourier Transform in the early 1970's that made the digital computer a viable approach to the problem.

These efforts primarily at NBS and Georgia Tech demonstrated to the technical community that planar near field scanning and transformation yielded reliable results and compared in accuracy with good far field ranges. Its application was limited to a conical sector in front of the antenna.

Initial work began on cylindrical scanning but thorough evaluation has to this date not been done. This scanning technique has neither the simplicity of planar scanning nor the potential utility of spherical, and as a result has not attracted the development funds of the other two.

Extensive work has been done at both NBS and the Technical University of Denmark (TUD) on spherical scanning. The European Space Agency has funded work at TUD

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[1]Joy, E.B. et al, "Spatial Sampling and Filtering in Near Field Measurement", IEEE Transactions on Antennas and Propagation, Vol. AP-20, No.3, pp. 253-261 May, 1972.

as well as Marconi in England and is committed to its implementation. TUD has an operating software package but it has the disadvantage that the large memory requirements for the computer requires that the transformation be done in off hours and as a result, a period of 24 hours is required to obtain far field data.

NEAR FIELD MEASUREMENTS VERSUS FAR FIELD MEASUREMENTS

As was discussed above, much work has been done toward developing viable near field test techniques. These techniques have many advantages as well as disadvantages. Measurements made with far field test techniques have many advantages as well. These advantages are as follows.

(1) The characteristics of the antennas are measured directly and the waiting period required for complete data collection and far field transformation is not required.

(2) It has wide acceptance by the industry as a result of many years of study and proven reliability. These techniques are well understood.

There are, however, many disadvantages to far field testing as well as the advantages listed above. One of the greatest disadvantages is that a considerable real estate investment is usually required for the facility. Tests must be made on facilities which are sufficiently long to provide acceptable phase errors. The size of this facility frequently dictates that it cannot be located in close proximity to the laboratory or manufacturing complex. In such cases, cost of transportation and liason between two facilities are also incurred. In addition, many scheduled interruptions result from adverse weather conditions such as rain, wind, ice and snow. For many precision tests, solar deflections must also be accounted for.

For these reasons, near field testing has become increasingly attractive for certain applications in recent years and will become more so in years to follow. Near field testing permits a facility to be contained in a much smaller space, thereby reducing investment in real estate and is much more amenable to an indoor environment. It is much easier to locate such a facility in close proximity to the production line or laboratory and thereby eliminate the expense associated with the remote facility. By containing the facility in a smaller space, it is also much easier to control unwanted reflections.

With all these advantages, then why haven't near field measurements already replaced far field measurements as a means of testing for many applications? They are not yet widely accepted or understood by the industry and many of the techniques have yet to be verified to the satisfaction of the antenna community. Standard products do not currently exist which will allow near field systems to be implemented. A further disadvantage is that all the near field data must be gathered before any of the far field results can be obtained. Once this data is gathered, there is a delay while waiting for the computer to calculate the far field results. One exception to this is the compact range which measures the antenna characteristics directly and does not require a computer to reduce this data in order to achieve the final result.

DESCRIPTION OF NEAR FIELD TECHNIQUES

There are several near field techniques which are in use or under development. These are as follows.

(1) Planar Scanning
(2) Compact Range
(3) Cylindrical Scanning
(4) Spherical Scanning

Planar near field measurements utilize a field probe positioner such as the line drawing shown in Figure 1. A probe antenna is mounted on the central carriage member which moves vertically or in the Y direction as shown. The entire vertical member moves horizontally or in the X direction as shown. The test antenna is placed in front of this positioner and can be moved longitudinally or in the Z direction. This technique has particular application for planar antennas such as many phased arrays and can be used for antenna measurements as well as for adjustment of phase shifters in such arrays and for element interrogation. It gives good results in a limited angular sector in front of the test antenna. It does not give information about the wide angle side lobes or back lobes of the antenna under test. The primary obstacle to producing scanners for this mode of testing is the wide range of sizes and accuracies required.

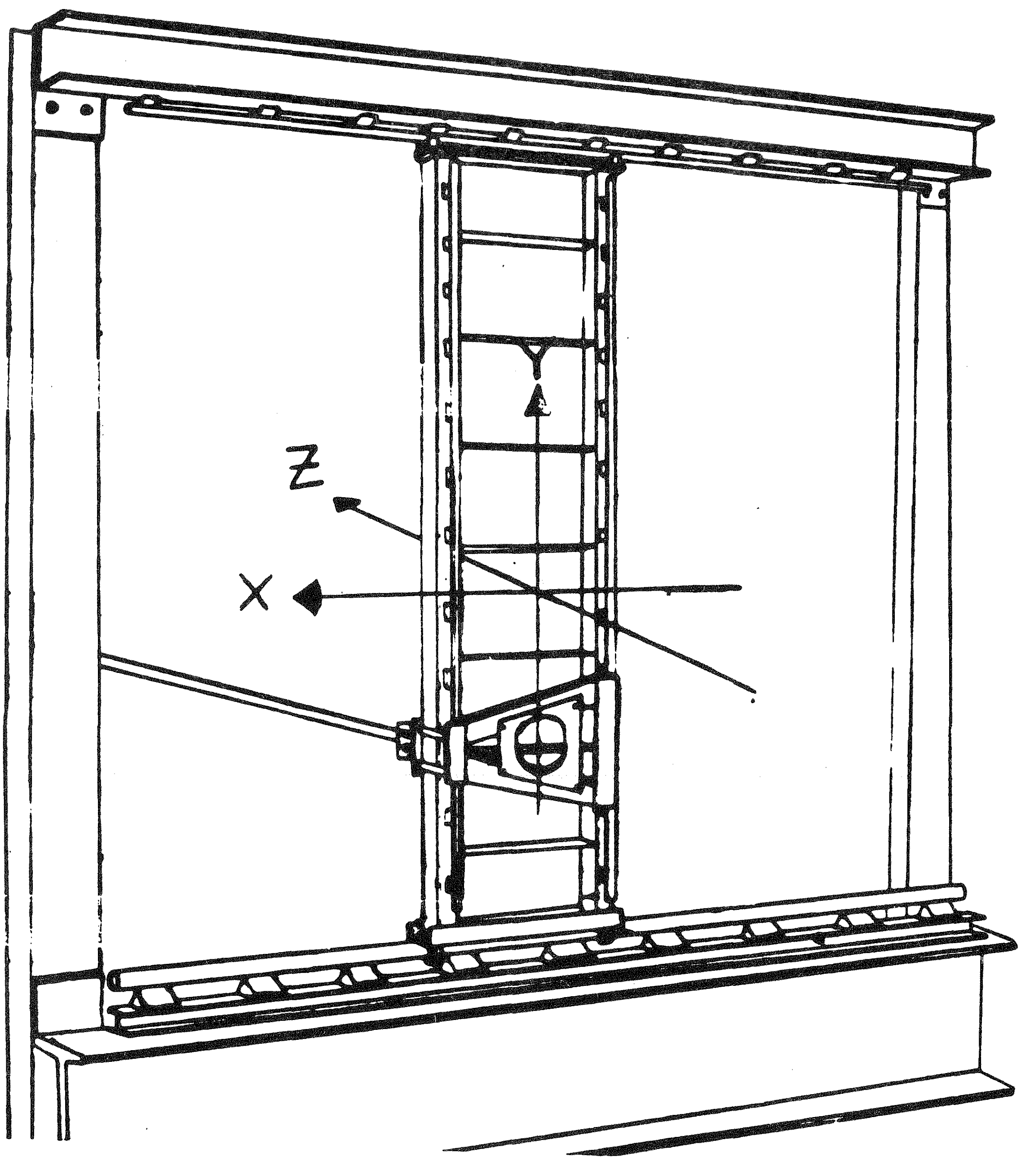

Figure 1. Basic Design of Planar Scanning

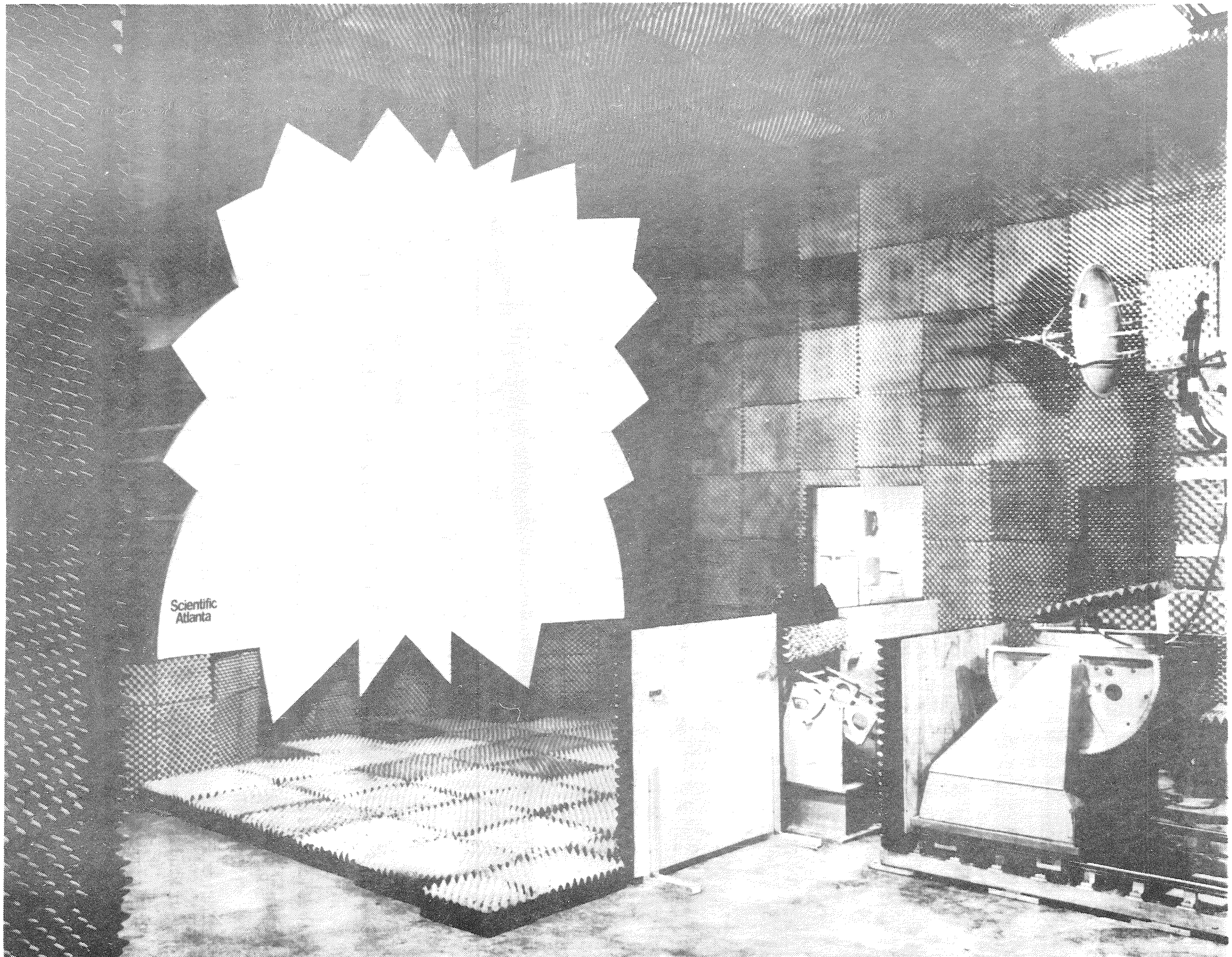

Figure 3. Compact Range Facility

The compact range is a near field device which has begun to receive wide spread acceptance. It was invented by Dr. Johnson at Georgia Tech in the late 1950's.[2] It has the advantage that far field characteristics are measured directly and no transformation is required. The compact range produces a uniform plane wave in the immediate vicinity of the test antenna. The diverging rays from a point source feed are collimated by a large source antenna and this plane wave illuminates the antenna under test. This configuration is shown in Figure 2. The primary advantage of the compact range is that the entire facility can be located indoors. Antennas which would normally require long outdoor ranges can

or external interference. Typical compact range performance characteristics are as shown below:

Frequency Range	4-18 GHz
Test Zone	4 Ft. Diameter
Amplitude Taper	$\leq$ 0.5 dB
Amplitude Variation	$\leq$ 0.3 dB
Phase Variation	< 5 Degrees
Cross Polarization	- 35 dB

Very precise antenna measurements can be made on the compact range and measurement accuracies comparable to precision far field facilities are now commonplace. A photograph of a compact range facility is shown in Figure 3.

Cylindrical scanning is a technique in which the surface of a cylinder containing the antenna is defined and data points are taken at periodic intervals on this surface. The positioner required is much simplier than that for the planar configuration. A linear probe positioner is built which will move the probe antenna in a straight line parallel to the cylindrical axis. Angular movement is accomplished by placing the test antenna on a positioner whose axis of rotation is parallel to the linear travel of the probe antenna. This permits a cylinder containing the test antenna to be precisely scanned. This data is then reduced by a computer and the far field results obtained. It has the advantage that a much greater portion of the antenna's far field characteristics

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[2]R.C. Johnson, "Antenna Range for Providing a Plane Wave for Antenna Measurements," U.S. Patent No. 3,302,205; 32 January 1967.

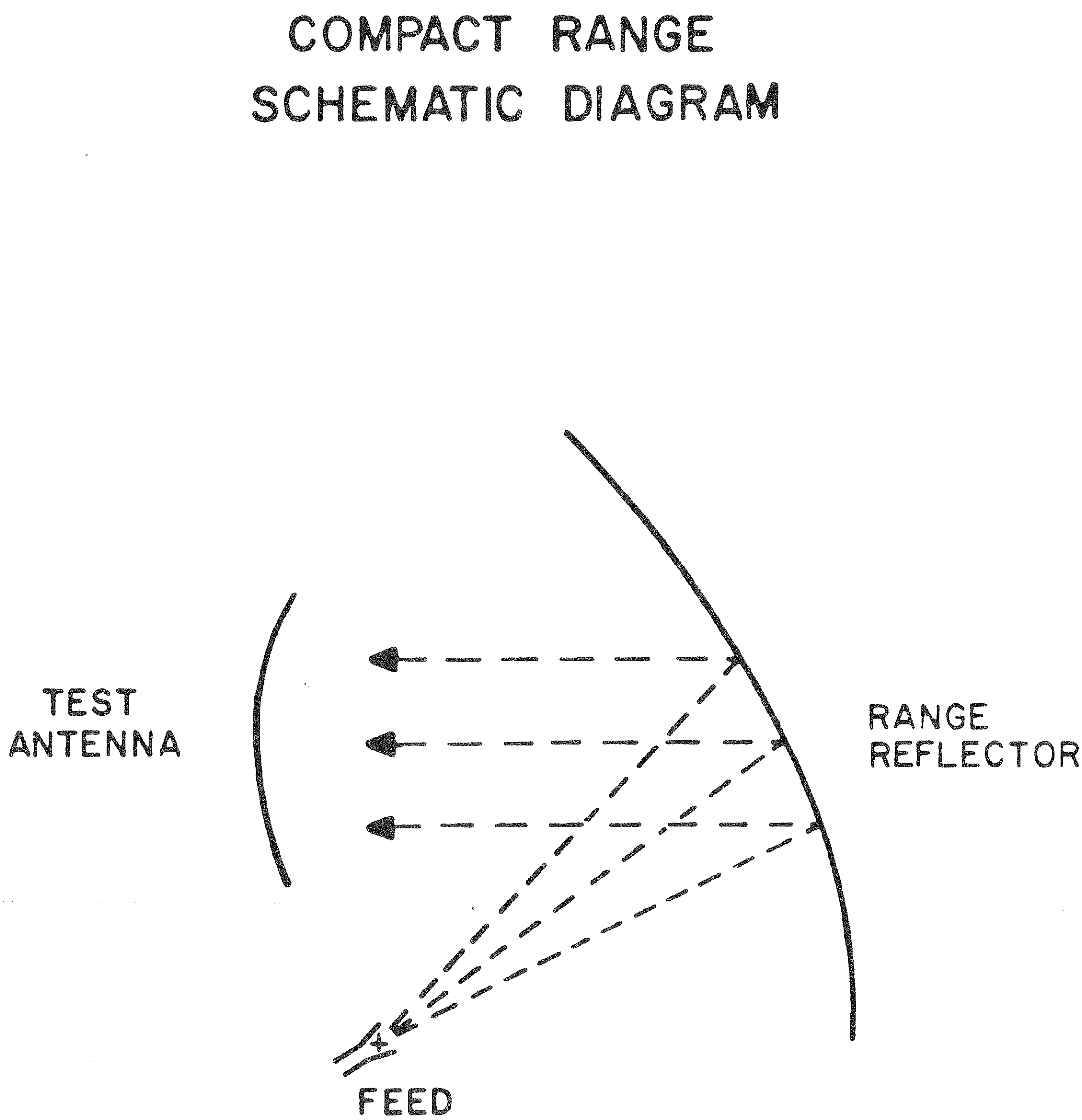

Figure 2. Schematic Drawing of a Compact Range

can be evaluated than with the planar scanning technique alone. Wide angle side lobes and back lobes can be evaluated and only narrow angular sections close to the cylindrical axis are omitted.

While cylindrical scanning does seem to be a significant improvement over the planar technique for many applications, it is spherical scanning that appears to have the most promise in the coming years. Conventional antenna positioners which orient the antenna in its spherical coordinate system can be used for spherical near field measurements. With positioners readily available, special positioners need not be designed as in the previous two cases. This technique has the further advantage that the entire sphere can be evaluated and there are no open sections.

The software for the spherical system is considerably more complex than for planar or cylindrical methods of scanning. However, a great deal of progress has been made in this area and standard product systems will soon be available to companys wishing to implement this measurement technique. Scientific-Atlanta is in the final stages of a development program for such a system. This system, the Model 2022 Spherical Near Field Antenna Analyzer was developed around the Model 2021 Antenna Analyzer and will be introduced January 1, 1979. It is particularly attractive because a dedicated mini-computer will be a part of the system and the usual interface with an external computer will not be necessary. The system will have the capability of gathering data at a given radius and transforming it to a second radius which includes but is not limited to infinity. It will handle antennas up to 80 wavelengths in diameter and operate at frequencies through 18 GHz. The availability of this standard product will eliminate the necessity of developing a special system for a given antenna and thereby provide a cost effective solution for this measurement technique. This system will have particular application to companys who have existing anechoic chambers or those who are planning anechoic chambers.

Those with existing anechoic chambers invested a great deal of money in them because they wanted to test in an indoor environment. This investment is a company asset on which it wishes to maximize its return. By investing in a near field system, it can extend the use of this chamber to operate at much greater ranges.

Companys who anticipate building anechoic chambers can build much smaller facilities than would be required for far field testing and thereby save a great deal of money which will furthermore make indoor testing possible and applications which would normally be out of the question. A 180' anechoic chamber for example might easily cost in excess of $2 million. This cost would be prohibitive in most companys whereas a 50' chamber would be readily affordable and could probably serve the purpose with a near field system.

If existing outdoor ranges become obsolete due to a new testing requirement which requires a much longer range than the existing range, they can frequently be used with a near field measurement system which would transform the data to an infinite radius.

In summary, near field systems will soon be commercially available to companys wishing to take advantage of the attributes of near field testing. Heretofore, special systems had to be designed and constructed or conventional far field systems which had to be used. The advantages of near field systems presented earlier in this paper can now be realized and results already obtained with the compact range will soon be available for spherical near field scanning.