USE OF CLUSTERED FEEDS IN A COMPACT RANGE FOR RCS MEASUREMENTS

Marion C. Baggett and Dr. William G. Swarner

Scientific-Atlanta, Inc.
4357 Park Drive Suite E
Norcross, Ga. 30093

ABSTRACT

Increased productivity and higher resolution imaging capabilities are becoming of greater concern for RCS ranges. The ideal measurement scenario involves taking data on all desired frequencies for a target configuration in a single rotation. This could involve one or more frequencies in several bands, imaging data on more than one band or very high resolution imaging data covering several bands. Placing several feeds in a cluster at the focal point of an offset fed com-pact range can provide these capabilities. The effects of feed clustering such as beam tilt are discussed along with cluster sizes that provide little if any degradation in compact range performance. Experimental data is shown that gives an indication of the quality of data that may be obtained. The concepts are also applicable for outdoor ranges that have an array of antennas offset from range boresight.

Keywords: Feed Cluster, Productivity, Compact Range

1. FEED CONFIGURATION ALTERNATIVES

The current alternatives in multi-band operations with a compact range have included 1) placing single feeds at the focal point of the reflector and taking data on each band or sub band and 2) using automatic feed carousels. With dual reflector systems, the feeds have been mounted on turntables, using one feed at a time. In all of these cases, physical movement of the feeds is needed to move from band to band. Manually mounting and dismounting feeds creates a high labor overhead in range throughput. In addition, the data may have to be merged from several data runs during post processing. While computationally presenting no difficulties, the time required for feed changes and possibly dismounting the target between runs to check feed alignment can lead to significant data variations between runs. An automatic feed carousel reduces labor and re-alignments, but a penalty is paid by the increased cost and complexity of the feed system, while still having only one feed in use at a time for a given data cut. Wide band feeds have been used to obtain multi-band data. However, for short pulse systems, it has been difficult to design feeds that provide wide band width, proper beam shape across the bandwidth and higher power capability that the larger compact ranges require. In addition, wide band feeds are more susceptible to modal effects in small frequency regions that may produce resonances.

Creating a cluster of feeds that are each optimized for performance over a smaller band would seem to be an attractive alternative. A fixed system with no motion required simplifies the feed mount and its connections to the radar. Fast antenna selection at the PRF rate is well within current technology. By optimizing each feed for a smaller bandwidth, better beam shape and the elimination of resonant modes result. Feed clustering does come at a cost of some degradation in quiet zone size and quality in that at best, only one feed may be located at precisely the focal point. This degradation can be kept within reasonable limits as discussed in succeeding paragraphs.

2. CONCERNS IN FEED CLUSTERING

2.1 PHYSICAL ARRANGEMENT

The first issue in feed clustering is determining the physical shape of the cluster. A compact range reflector is normally of a vertical offset fed design to minimize feed-reflector coupling. The offset is carefully chosen to optimize this coupling while having minimum effect on cross polarization isolation and vertical field taper. Any clustering in the vertical dimension would have effects in these areas. A horizontal clustering would have less effect and was the method chosen. Figure 1 shows the actual feed cluster used, as shown from the top. The horizontal offset in inches to the center of each feed from the focal point is shown. All feeds were dual polarized ortho-mode feeds.

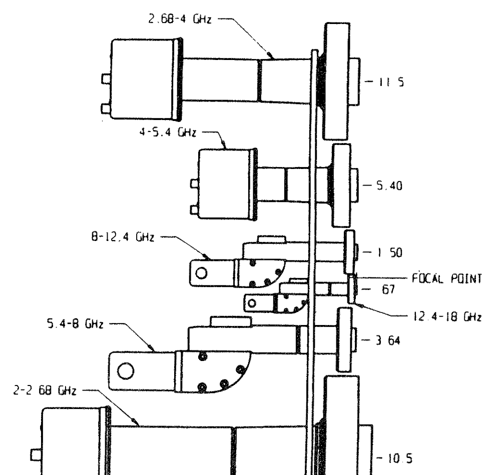

Figure 1: 2 to 18 GHz Feed Cluster

2.2 BEAM TILT

The first order effect of horizontally offsetting a feed relative to the focal point is to shift the beam axis relative to the axis of the chamber by an angular amount equal and opposite to that of the feed offset. This situation is shown in Figure 2. The target, in this case a horizontal cylinder oriented normal to the range axis, will be effectively measured as though it were oriented with clockwise rotation relative to the actual normal orientation if the feed were at the focal point. If the feed offset is known, this offset can easily be compensated by the data extraction and processing software.

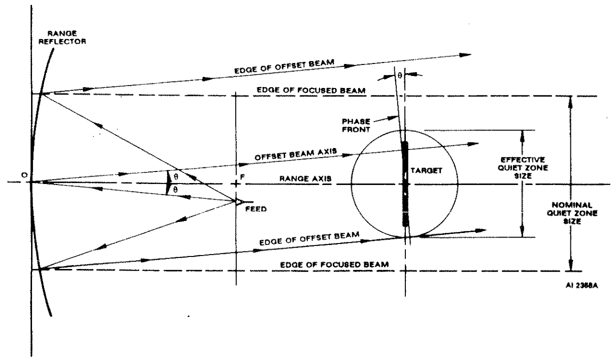

Figure 2: Effects of Displacing Feed Laterally

2.3 QUIET ZONE SIZE

Of greater consequence is the reduction in effective quiet zone size as shown in Figure 2. Assuming that the target remains centered within the chamber, the effective size of a circular or other axially symmetric quiet zone is limited by the nearest edge of the offset beam. Figure 3 shows a predicted quiet zone for a Scientific Atlanta

Model 5704 reflector at 5 GHz for a feed at the focal point. The second curve shows the effect of offsetting the feed by 10.5 inches. Note that the normally defined quiet zone (region within +/- .5 db of variation) is shifted opposite to the feed movement. Note that feeds on both sides of the focal point would reduce the effective quiet zone on both sides. It can be seem that to a first approximation, for a quiet zone located 2 focal lengths from the reflector vertex, the quiet zone width is reduced by twice the horizontal displacement of the feeds. That is, if a feed cluster on a range with a 12 foot quiet zone was constructed with feeds offset 5 inches on one side and 6 inches on the other, the resulting quiet zone would be 10' 2". These effects can be reduced somewhat by moving the feeds in an arc away from the reflector instead of a straight line perpendicular to the reflector. In addition, reflectors such as the Scientific Atlanta Model 5708 reflector have quiet zones that are limited by feed taper, not reflector size, so that in practice, little actual loss in size may occur.

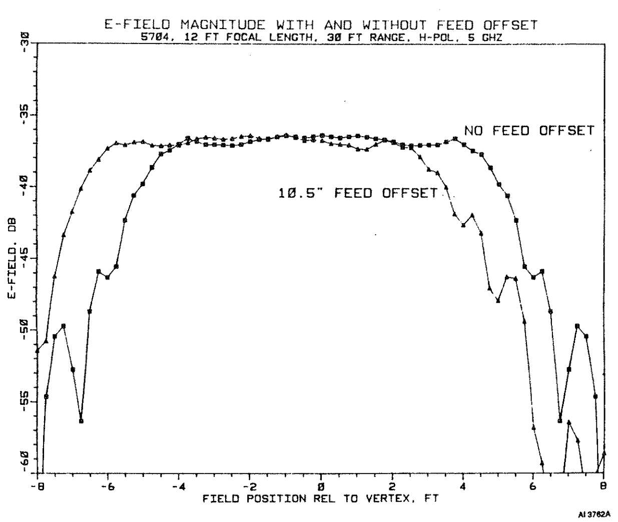

Figure 3: Quiet Zone - Reflector at 5 GHZ
For A Feed at the Focal Point

2.4 AMPLITUDE TAPER

As can be seen from Figure 3, the shape of the amplitude taper across the quiet zone does not change appreciably. Figure 4 shows a comparison of predicted amplitude tapers for various lateral feed offsets, showing that this performance parameter is not affected to a large degree.

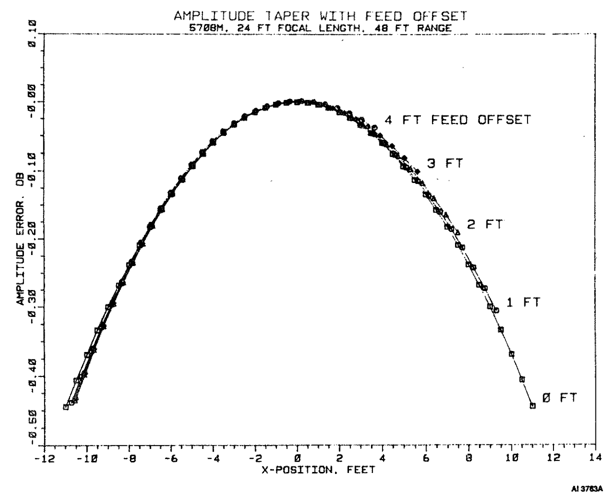

Figure 4: Amplitude Taper with Feed Offset

2.5 PHASE TAPER

Figure 5 shows the predicted phase variation for several lateral displacements of the feed. The absolute phase fronts have been aligned by re-focussing the feeds as required by shifting the feeds slightly from the "nominal focal distance" parallel to the range axis. The curvature of the plot represents the remaining phase front curvature. From the curves of Figure 5, we see that very little phase error is incurred by using feed offsets up to about 1 foot, which represents an angular offset of approximately 2.4 degrees for a 24 foot focal length reflector. Note that by placing the higher frequency feeds, which will be relatively smaller, at the center of the cluster, the phase error is minimized. At the lower frequencies, which have relatively larger feeds, the wider spacing will still maintain very little measurement error.

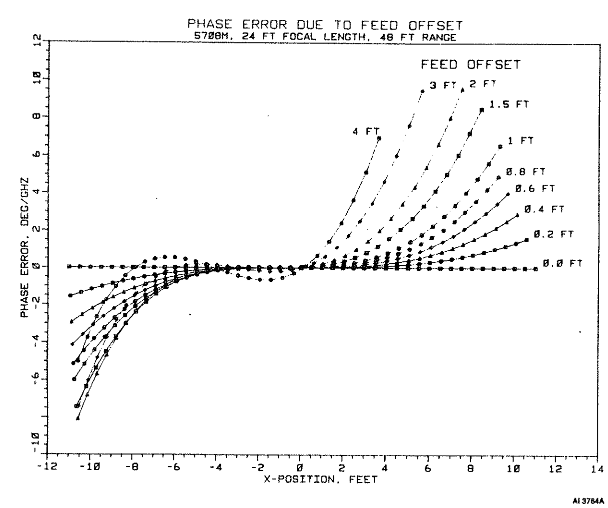

Figure 5: Phase Error Due to Feed Offset

2.6 SIDE LOBE ASYMMETRY

A final effect of feed offset which can become apparent in RCS measurements of a highly specular symmetrical target such as a flat plate or cylinder is an asymmetry of the near-in side lobes adjacent to the specular region. Figure 6 shows the presence of the asymmetry for a horizontal cylinder. As is well known, the accurate measurement of these side lobes is very difficult in a compact range since at small orientation angles relative to normal incidence, the specular return from range reflector edge diffraction can be comparable to the normal side lobe return. The practical significance of this effect depends on the particular type of measurements to be made. In typical RCS measurements of low observables, it may be more important to obtain measurement accuracy farther removed from the specular region than in the near in side lobe region where a slight shift in vehicle aspect would allow the target to be detected via specular return.

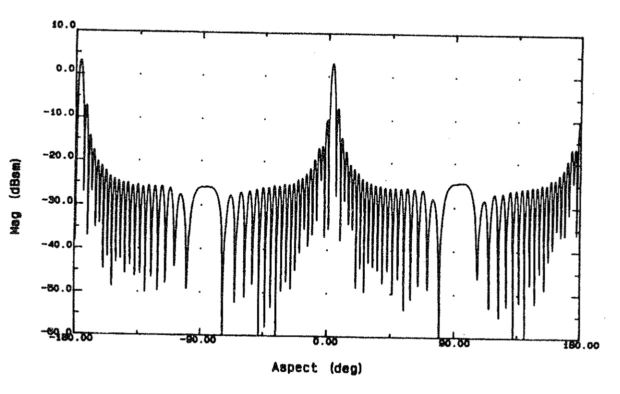

Figure 6: Asymmetry for Horizontal Cylinder

When the feed is offset from the focal point, the ray paths which produce this near in side lobe error become asymmetric. The principal ray paths will remain approximately equal. However, the offset has a larger effect for the edge diffracted paths. The result is that when the signals represented by the ray paths combine vectorially to produce the side lobe pattern as a function of target rotation, the side lobes will, in general, be asymmetric. This does not represent an increase in measurement error since the error mechanism is still essentially the same as when the feed is located at the focal point. Thus the magnitude of the near-in side lobe error remains the same but its presence becomes more apparent because of the asymmetry of the resulting pattern.

2.7 DATA PROCESSING

To a first order approximation, the offsets of the feeds will translate to a "look angle" offset in the data. If single frequency measurements are performed, the feed will be "looking" at an aspect angle corresponding to the size of the feed offset angle. The effect is to place scattering centers at the "wrong" angle. For example, if a perfectly aligned horizontal cylinder (broadside at 0.0 degrees aspect angle) were measured with a feed of 2.5 degrees offset, the broadside peak appears at -2.5 degrees.

The problem is compounded in wide band measurements. Many imaging Nyquist criterions require data at 0.1 degree or finer increments. This could put frequencies that need to be imaged many aspect increments away from each other.

The solution is to maintain a set of feed offsets in the processing software. When data on a frequency or frequency band corresponding to a particular feed is needed, the data file is searched with that feed's offset. However, this technique works well only if the data was keyed on target position. Some systems set a target rotation rate and then collect data at regular intervals, assuming a constant rotation rate. For many target/support/positioning configurations, variations in target motion rate can occur due to such effects as backlash error shifts when a target torque shifts due to target rotation.

For imaging, the software must extract the portions of frequency data appropriate for each image angle from several frequency sets. A requirement for this compensation is that the raw data must extend far enough on either side of the desired image slice to cover the feed offsets. For example, if an 11 degree image is needed and the furthest feeds have offsets of 2.5 degrees on either side, 16 degrees of raw data must be collected. This is usually not a problem since full rotation cuts are taken in most measurement scenarios.

3. EXPERIMENTAL RESULTS

3.1 EQUIPMENT

A feed cluster such as shown in Figure 1 was implemented with feeds for 4 to 5.7, 5.7 to 8, 8 to 12 and 12 to 18 GHz. This cluster was mounted in a compact range facility with a Scientific Atlanta 5704 compact range, giving a quiet zone of approximately 6 feet in width. The radar was a Scientific Atlanta Model 2090 pulse radar, which can provide feed switching at the PRF rate up to 100 Khz. Two RF units were used to drive the four feeds.

3.2 ASPECT DATA

Figure 7 shows data on a horizontal cylinder of 48 inch length and 6 inch diameter. The figure shows an overlay of single frequency data on the cylinder at 5, 7 10 and 15 Ghz. Note that the broadside returns are separated, particularly the 7 Ghz on the left and the 5 Ghz on the right. Since the X and Ku band feeds were much closer to the focal point, their offsets are considerably smaller. Figure 8 shows the overlaid plots at the 4 frequencies with the processing software compensating for the feed offsets.

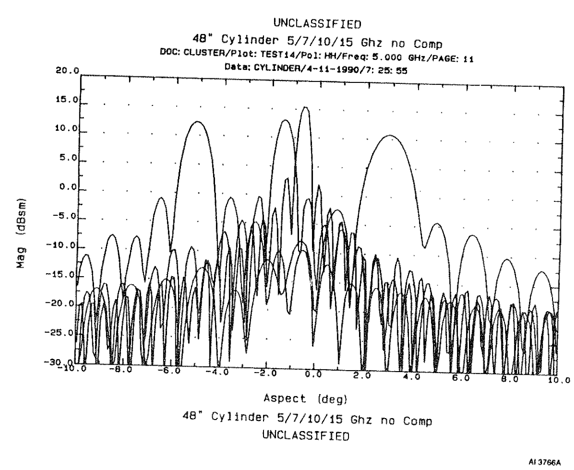

Figure 7: Uncompensated Multi-Frequency Scan

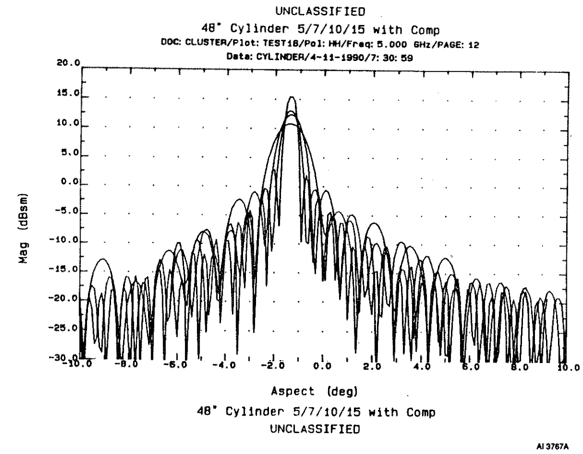

Figure 8: Compensated Multi-Frequency Scan

3.3 IMAGING DATA

The cylinder was imaged with 192 frequencies from 4 to 17 Ghz in a single rotation. Figure 9 shows imaging across all of C band, which uses the two feeds that are farthest offset. Since the data at a single aspect is offset in opposite directions for each sub band, the image is highly degraded. Figure 10 shows the results of applying the known feed offsets as the data is processed. Figure 10 shows an image of the entire 192 frequency set. Note that the image down range resolution has improved so that the 8:1 length to diameter ratio of the target is more apparent. This shows that imaging across 4 feeds can produce very high resolution images.

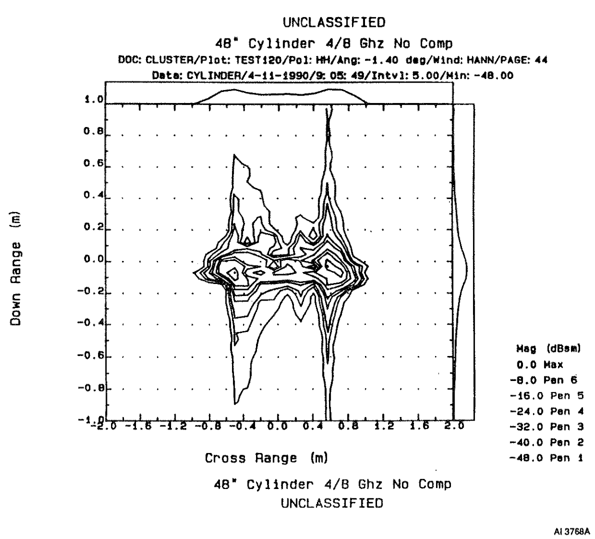

Figure 9: Uncompensated C-band Image of Cylinder

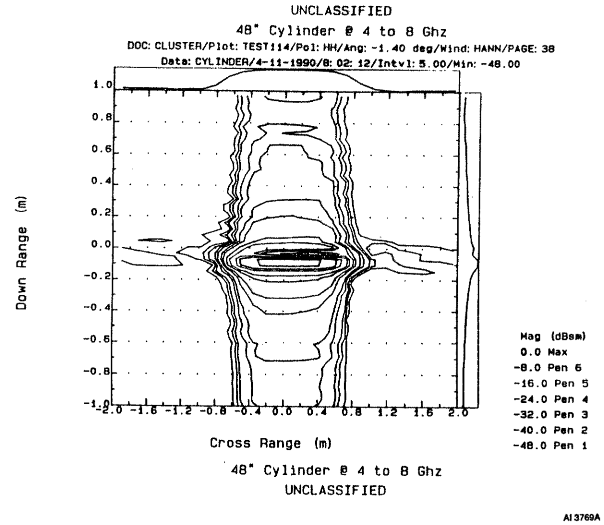

Figure 10: Compensated C-Band Image of Cylinder

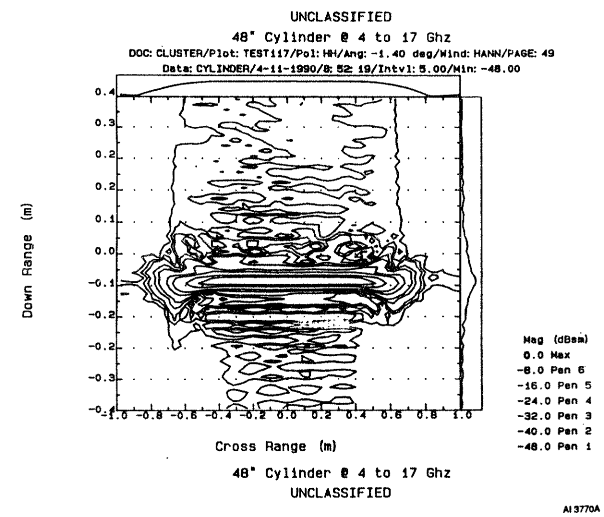

Figure 11: Compensated 4-17 GHz Image of Cylinder

4. CONCLUSIONS

Feed clustering can provide significant improvements in range through put and image resolution. The predominant effect of feed clustering is to slightly shrink the cross range quiet zone. Feed offsets of less than 1 foot produce little amplitude or phase taper degradations. Feed clustering allows optimization of feed characteristics over smaller frequency bandwidths, resulting in less expensive feeds and the capability to achieve higher power systems. The compensation technique for data analysis can be used effectively with clustered feeds or outdoor range antenna farms.