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Beam Spoiling a Reflector Antenna with Conducting Shim

Armin W. Doerry

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Armin W. Doerry
ISR Mission Engineering
Sandia National Laboratories
Albuquerque, NM 87185-0519

Abstract

A horn-fed dish reflector antenna has characteristics including beam pattern that are a function of its mechanical form. The beam pattern can be altered by changing the mechanical configuration of the antenna. One way to do this is with a reflecting insert or shim added to the face of the original dish.

Acknowledgements

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Foreword

This report details the results of an academic study. Any resemblance to any modes, methodologies, or techniques employed by any operational system is purely coincidental, and not intended by the author.

The specific mathematics and algorithms presented herein do not bear any release restrictions or distribution limitations.

This distribution limitations of this report are in accordance with the classification guidance detailed in the memorandum "Classification Guidance Recommendations for Sandia Radar Testbed Research and Development", DRAFT memorandum from Brett Remund (Deputy Director, RF Remote Sensing Systems, Electronic Systems Center) to Randy Bell (US Department of Energy, NA-22), February 23, 2004. Sandia has adopted this guidance where otherwise none has been given.

This report formalizes preexisting informal notes and other documentation on the subject matter herein.

1 Introduction & Background

As is so often the case with radar designs, applications arise after the radar becomes operational that exceed the original design requirements in some fashion. These often necessitate redesign of some aspect of the radar.

An antenna's beam pattern is typically fixed by its electromechanical design, which is often optimized for its original design mission. A discussion of the relationship of antenna characteristics to Synthetic Aperture Radar (SAR) performance is given in other reports.¹

Should the mission change, often another antenna design becomes optimal. For example, a SAR antenna designed with a narrow beam for long-range operation may not be capable of fine resolution stripmap which requires a wider beamwidth. Consequently, the problem arises of how to make a long-range SAR perform fine resolution strip-mapping. However, the original missions may not have abated, thus requiring an ability to revert to the original antenna performance. Consequently, means are required to adjust the beam pattern of the antenna. The question became "How do we do so?" The answer is the topic of this report.

Array antennas, especially active array antennas composed of Transmit/Receive (T/R) modules may offer the ability to disable certain radiating elements, thereby altering the antenna beam pattern. Reflector antennas generally do not offer such an option. Nevertheless, a system with a reflector antenna may be called upon to serve a function other than for which it was originally developed. Consequently other beam modification strategies suitable for reflector antennas need to be employed.

Preferable are techniques that are real-time programmable, that is, beams that are able to be redefined in-flight. However, 'wrench-programmable' solutions that allow easy modification on the ground between flights are often quite acceptable. It is this class of wrench-programmable reflector beam modification techniques that are the topic of this report.

Herein we use the term dish antenna and reflector antenna interchangeably.

“Nothing endures but change.”
-- Heraclitus (540 BC - 480 BC), from Diogenes Laertius, Lives of Eminent Philosophers

2 Discussion

A microwave antenna's far-field beam pattern (width, shape, etc.) is defined by its aperture illumination function. This is set by the aperture size, shape, and illumination taper. For a dish antenna, this is in turn set by the dish size, shape, curvature, and how it is illuminated. Dish illumination is typically by a horn antenna which has its own illumination function, but may sometimes use other techniques instead, e.g. a small array in lieu of the horn.

Antennas are frequently designed to provide as narrow a beam as possible for given sidelobe constraints. For many applications spatial resolution is a function of beamwidth, and narrower beamwidth provides improved resolution and location accuracy. Narrow beams are generally accompanied by higher gain, which is usually desirable in and of itself.

For a dish antenna we reiterate that the following items affect the beam pattern characteristics, including beam width:

- Dish illumination (by, for example, a horn's own pattern)

- Dish placement/orientation

- Dish size/shape

- Dish curvature

Altering any of these characteristics will cause the antenna beam pattern to change, too.

In the following discussion we concern ourselves with achieving a broader beam width from an existing antenna by modifying it in some fashion. We shall presume a horn-fed dish antenna.

2.1 Dish illumination

By modifying the dish illumination to focus more power onto a smaller area of the dish, a wider beam width will result. Seemingly paradoxically, often a narrower horn pattern will generate a wider pattern reflecting from the dish itself. This is illustrated in Figure 1.

Figure 1. A larger horn feeding a dish will illuminate a narrower region of the dish, thereby increasing the beamwidth from the dish.

2.2 Dish placement

The relative position of horn and reflector dish is typically such that the horn is at the focal point of the parabolic dish reflector. This results in the narrowest reflected beam width. The reflected beam is effectively focused to infinity. By moving the horn closer to the dish, without altering the dish curvature, the reflected beam is 'defocused' to a wider beam width. This is illustrated in Figure 2.

Figure 2. Moving the feedhorn away from the focal point of the dish will defocus the beam achieving a wider beamwidth.

2.3 Dish size/shape

The dish size and shape constitute the real aperture of the overall antenna. By making the reflector smaller, the aperture is reduced and a wider beam width in the far field will result.

One option is to in fact substitute a smaller reflector for the original reflector, or physically remove portions of the original reflector.

A second option is to render a part of the original reflector as non-reflecting. This might be achieved by calculated placement of microwave absorber material. This is illustrated in Figure 3.

The down side to this approach is a decrease in efficiency due to energy from the horn either not reaching a reflector surface, or being absorbed in regions of the reflector. This is sometimes referred to as 'spill-over'.

Figure 3. A smaller dish surface will result in a wider beamwidth.

2.4 Dish curvature

As previously stated, the relative position of horn and reflector dish is typically such that the horn is at the focal point of the parabolic dish reflector. However, if the curvature of the reflector were changed, then the focus at infinity is 'spoiled' such that a wider reflected beam results, similar to the dish placement change.

A physical deformation of the dish is generally not possible due to the stiffness required for airborne operation. However, dish curvature can be affected by attaching a reflective insert or shim to the original dish reflecting surface. This is illustrated in Figure 4.

Figure 4. A reflective insert or shim will alter the dish curvature, thereby altering the focus properties of the antenna, and spoiling the beam.

This might also be possible with a shaped dielectric layer in the signal path between horn and reflector surface, to act as a sort of microwave corrective (distortive) lens. However, we would expect a reflective insert to have wider bandwidth. A dielectric lens in the beam of the main reflector is another option.

Modifying the dish curvature with a reflective insert or shim is the topic of the remainder of this report.

3 Antenna Shim Simple Example

We present here a simple one-dimensional example illustrating the basic concept of shimming a dish antenna.

Figure 5 is a plot of an example antenna reflector geometry. The blue star is the focal point of the blue parabola. This represents a dish reflector and feed point. The red is a ‘shimmed’ reflector, that is, a new reflecting surface in front of the old reflecting surface. We also assume a -25 dB Taylor weighted dish aperture taper as representative of the horn’s illumination pattern.

Figure 6 shows the patterns of the original antenna and the shimmed antenna as a function of angle in degrees for an 18 mm wavelength. The beam has been broadened by a factor of three, from 2.55 to 7.5 degrees. Clearly, we have significantly broadened the beam with the inserted shim.

Figure 5. Original focused antenna geometry is in blue. Red represents the reflective shim surface.

Figure 6. Original antenna beam pattern in blue. Beam pattern of shimmed antenna in red. Gains are normalized to respective peak values. Both patterns assume 18 mm wavelength.

4 Summary Discussions and Conclusions

Several comments are worth stating or restating.

- The antenna shim clearly affects antenna beam pattern shape, including its width.
- Proper control of the shim topology will allow control of the antenna beam pattern modification.
- Any mechanical modification may warrant a rebalancing of the antenna assembly on the gimbal pointing apparatus.
- A dielectric lens may also alter the antenna beam pattern in a similar manner, but with other factors that need to be considered, too.

*"Flexibility -- In all aspects of life, the person with the most varied responses "wins."
-- Kelly Perdew*

References

- ¹ A. W. Doerry, “Performance Limits for Synthetic Aperture Radar – second edition”, Sandia Report SAND2006-0821, Unlimited Release, February 2006.

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