3.4C ANTENNA INDUCED RANGE SMEARING IN MST RADARS

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INTRODUCTION

There is considerable interest in developing ST and MST radars for higher resolution to study small-scale turbulent structures and waves. At present most ST and MST radars have resolutions of 150 meters or larger, and are not able to distinguish the thin (40 - 100 m) turbulent layers that are known to occur in the troposphere and stratosphere, and possibly in the mesosphere. However the antenna beam width and sidelobe level become important considerations for radars with superior height resolution.

The objective of this paper is to point out that for radars with range resolutions of about 150 meters or less, there may be significant range smearing of the signals from mesospheric altitudes due to the finite beam width of the radar antenna. At both stratospheric and mesospheric heights the antenna sidelobe level for linear equally spaced phased arrays may also produce range aliased signals.

To illustrate this effect we have calculated the range smearing functions for two vertically directed antennas, (1) an array of 32 coaxial-collinear strings each with 48 elements that simulates the vertical beam of the Poker Flat, Alaska, MST radar, and (2) a similar, but smaller, array of 16 coaxial-collinear strings each with 24 elements. Figure 1 shows the one-way antenna pattern for the Poker Flat vertical antenna. The main lobe has a two-way beam width of 2.2 degrees. The smaller antenna has a two-way beam width of 4.4 degrees.

CALCULATION OF RANGE SMEARING FUNCTIONS

Referring to Figure 2, a thin turbulent layer is illustrated by the thick horizontal line. For a vertically directed antenna, R1 is the vertical range to the turbulent layer. However, because the antennas have a finite beam width with sidelobes, some energy is transmitted at an angle θ to the main lobe direction. The received power from the direction θ has a strength that depends on the antenna pattern, and originates from a range R2 = R1 + X. Therefore a function F(x) can be derived for a particular antenna that represents the variation of returned signal power as a function of distance (x) above a thin layer. For a thick turbulent layer, or multiple layers, the total radar echo response will be a convolution of the turbulence layer structure with the function F. This function is also height dependent, therefore, for illustrative purposes we will present calculations for heights of 85 and 15 km in the mesosphere and lower stratosphere, respectively.

MESOSPHERE

Figure 3 shows the range smearing function for the Poker Flat, Alaska, MST radar vertical beam antenna. Figure 4 is the same data covering only the first 100 meters that results from the main antenna lobe. The observed mesospheric signals in Alaska are frequently 20 dB or more above the minimum detectable level. These strong signals will be smeared in range up to 100 meters or possibly more for extremely strong signals.

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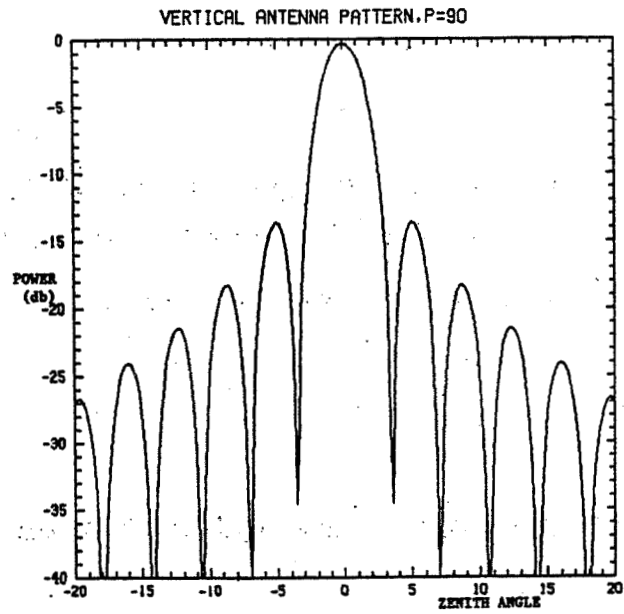**VERTICAL ANTENNA PATTERN,P=90**

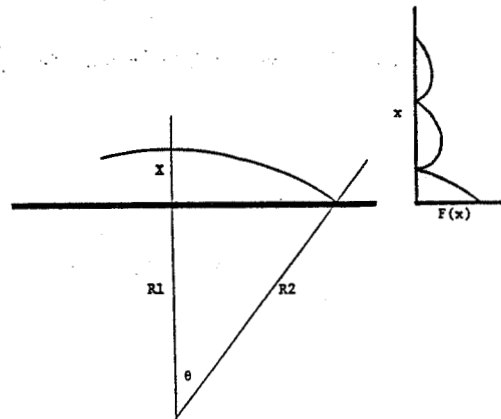Figure 1. Radiation pattern for a square array of 32 coaxial-collinear stings each containing 48 elements.

Figure 2. Geometry of two paths to a turbulent layer and the range smearing function F(x).
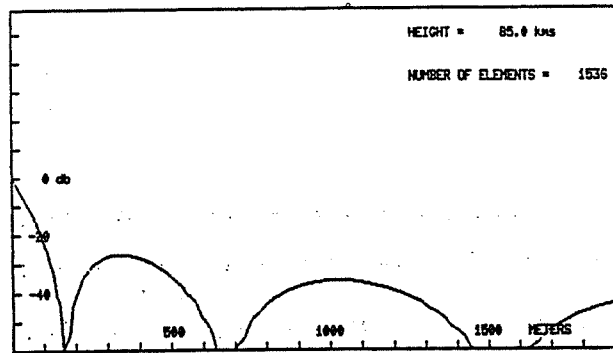
Figure 3. The range smearing function at a height of 85 km for an antenna composed of 32 coaxial-collinear strings each with 48 elements.
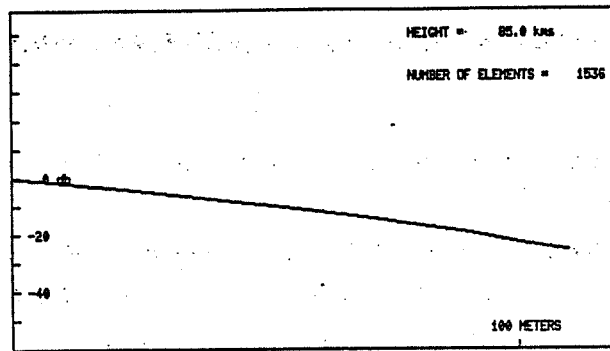

Figure 4. The same data as Figure 3 but only showing the first 100 meters.

With regard to the sidelobes, a very strong turbulent layer that produces signal returns more than 27 dB above the detectable limit will produce detectable signals at a distance of about 350 meters above the strong layer (see Figure 3). These range-aliased signals due to the first sidelobe are admittedly weak compared to the strong layer that produces them, but their magnitude may still be comparable with real turbulent layers at other heights.

For the smaller antenna (Figure 5) the situation is much worse. Range smearing due to the main antenna lobe extends more than 300 meters for signals stronger than about 20 dB above the detectable limit. If the signals are very strong (i.e. > 27 dB) the first antenna sidelobe may contribute signals from about 1100 to 1700 meters above the strong turbulent layer.

STRATOSPHERE

There is little problem with range smearing due to the main antenna lobe at low altitudes. Figure 6 for the Poker Flat antenna at 15 km altitude indicate less than 20 meters range spread which is probably a negligible error for most present or planned ST radars. However the smaller antenna shows more spreading (Figure 7); for an ST radar with such an antenna, a narrower beam antenna would be beneficial if high resolution is desired.
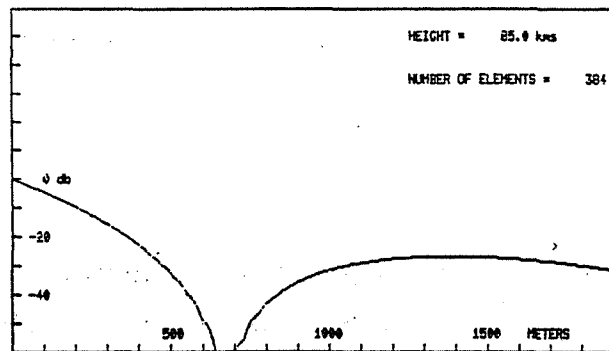
Figure 5. The range smearing function at a height of 85 km
for an antenna composed of 16 coaxial-collinear strings
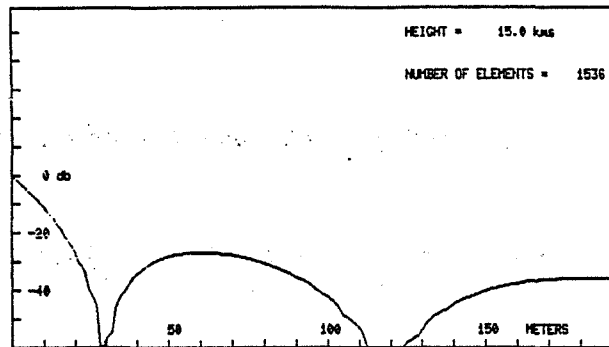each with 24 elements.

Figure 6. The range smearing function at a height of 15 km
for an antenna composed of 32 coaxial-collinear strings
each with 48 elements.

Concerning the sidelobes, the same problems exist in the stratosphere/
troposphere as was discussed above for the mesosphere. It has been established
from radar observations (WOODMAN, 1980), and balloon and smoke trail experi-
ments (GOOD et al., 1982a,b) that tropospheric and stratospheric turbulence
occurs in thin layers typically 30 - 100 meters thick separated vertically
about 100 - 200 meters apart.

The balloon data frequently indicate variations of turbulence levels > 20
dB. It is likely that if new radars are designed with sufficient resolution
to discriminate these thin intense turbulent layers, then antenna sidelobes
may contribute to the returned signals.

SUMMARY

It is suggested that finite width of the radar antenna main lobe may pro-
duce range smearing that is important for high resolution MST radars, especial-
ly at mesospheric heights. For an extremely turbulent layer, the returned
signals may be strong enough that the first antenna sidelobe is important.

Our calculations relate to vertically directed beams. For off-vertical
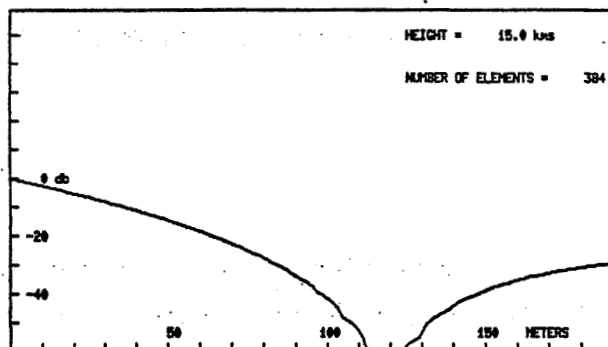antenna directions the problem is more severe.

Figure 7. The range smearing function at a height of 15 km
for an antenna composed of 16 coaxial-collinear strings
each with 24 elements.

We suggest that in the design of future high resolution MST radars con-
sideration be given to obtaining as narrow an antenna beam as is practical.
The average power-aperture product determines the radar sensitivity; therefore
it may be preferable to invest more in the antenna (to obtain a larger aperture
and narrower antenna beam) than in a high power transmitter.

The simple inexpensive linear equally spaced arrays (e.g., coaxial-col-
linear antennas) have first sidelobes that may be too large for high resolu-
tion studies. Sidelobe reduction is possible by utilizing nonequal spacing
or a tapered power distribution. For example, the UK MST radar (BOWMAN et
al., 1983) utilizes a Dolph-Chebychev power distribution to partially suppress
sidelobes.

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Good, R. E., J. H. Brown, A. F. Quesada, B. J. Watkins and G. B. Loriot (1982b),
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