

COMPACT RANGE TESTING OF HIGH POWER ANTENNAS

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ABSTRACT

Use of a compact range for testing high power antennas is generally limited to testing the antennas at low power levels. In most cases, this is adequate, but for antennas where the management and dissipation of power is a key test parameter, the antenna and transmitter must be tested at the design power level. If this testing is to be performed in a compact range, it is important that the energy be captured and safely dissipated because allowing the energy to be incident on the absorber could result in destruction of the facility. The chamber under construction for Hollandse Signaalapparaten in Hengelo, Netherlands is designed to receive this energy in a specific region of air cooled absorber and to dissipate the heat into the chamber as an added load on the HVAC system.

Key Words: Absorber Material, Compact Ranges, Power Dissipation, High Power

1.0 INTRODUCTION

Compact ranges were first developed by Scientific-Atlanta in the early 1970's as a means for testing antennas indoors. Since for most applications, transmit and receive tests are interchangeable and test results are essentially independent of power level, tests are usually conducted at low power levels with the test antenna operated in the receive mode, both indoors and outdoors [1]. However, transmit antennas with distributed amplifiers operated in saturation require that tests be conducted at actual design power levels with the test antenna transmitting. These tests are usually conducted outdoors in the far-field of the transmitting antenna where the power density is low. New innovations in compact range design now allow the test engineer the option of testing high power transmit antennas indoors at design power levels. Challenges that must be overcome in indoor, compact range testing are injury to personnel and damage to the chamber. Controlling stray radiation is the function of the shielded chamber. Capturing the RF energy focused at the compact range feed as heat and dissipating it safely is the scope of this paper.

Hollandse Signaalapparaten is building a compact range designed for conducting high power measurements. The chamber will be 22 meters long x 8.5 meters high x 12.8 meters wide. A separate control room will be 11 meters long x 3.75 meters wide. The control room will be divided into two sections, one for supplies, filters, and mechanical equipment, the second for the Scientific-Atlanta 2095 Microwave Measurement System, which will control the testing, and for associated Hollandse Signaalapparaten test equipment.

Figure 1 gives a three-dimensional conceptual view of the compact range looking from the reflector toward the feed positioner, the absorber fence, and the antenna-under-test (AUT) positioner.

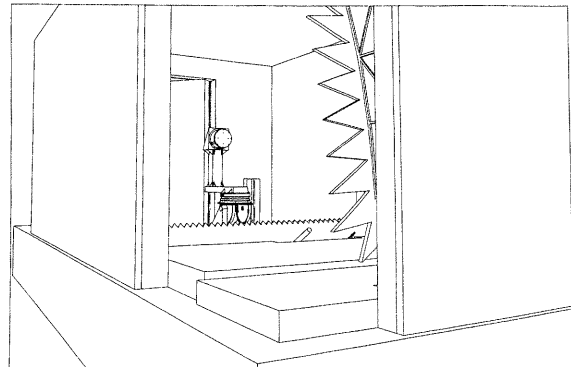


Figure 1. Three-dimensional Sketch of Compact Range.

2.0 REQUIREMENTS

2.1 POWER LEVELS

The APAR antenna for which this facility is primarily being built is an Active Phased Array Radar capable of transmitting more than 1 kW average continuous wave power. The antenna may be electronically steered. For full power testing of scanned beams, antenna patterns will be measured over $\pm 10^\circ$ centered on the beam peak by moving the lower azimuth axis in an elevation-over-azimuth positioner. Thus, the

area of the compact range where the high power will be incident will be limited to the area (centered on the focal plane which is tilted back approximately 27

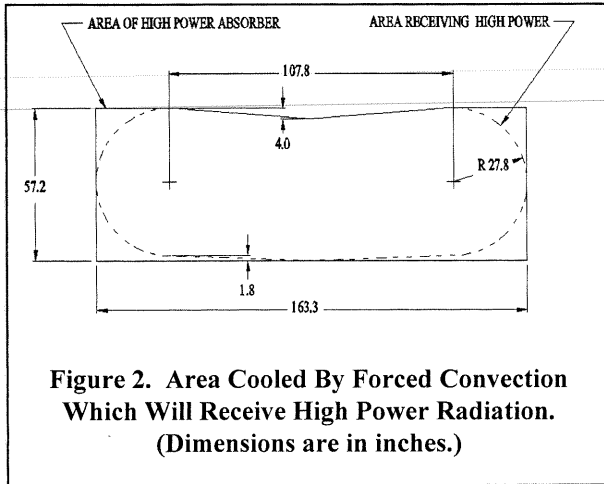


Figure 2. Area Cooled By Forced Convection Which Will Receive High Power Radiation. (Dimensions are in inches.)

degrees) shown in Figure 2.

2.2 MEASUREMENT SCENARIOS

As discussed in the previous subsection the compact range will be used for the purpose of making high power transmit pattern measurements of the APAR antenna for CW and pulsed RF. Additionally EIRP measurements will be made under high power conditions.

The APAR antenna will also undergo tests which will not involve high power emissions. Calibration will be carried out prior to receive or transmit pattern measurements being conducted. Receive pattern measurements which will be conducted over a hemisphere will allow aperture reconstruction for the purpose of element diagnosis. G/T and G/NF measurements will be conducted.

Figure 3 shows the configuration of the range instrumentation for high power transmit pattern measurements. The configuration can be switched automatically by the Compact Range Controller from the settings previously used for APAR calibration or receive patterns to the appropriate settings for transmit patterns. The attenuators ATTEN 1 and ATTEN 2 will be set as required for transmit pattern measurements. (The ATTEN 3 setting is "don't care" in the case of transmit patterns.) For transmit pattern measurements the RF signal from the Scientific-Atlanta Model 2180 Signal Source/2186 Frequency Synthesizer is input to the transmit/calibrate port of the APAR antenna unit (AU) by switching the first

switch (SW1) to position 2 and the "EIRP switches" to pass the RF signal to the AU. Some of the RF is coupled off from the Model 2180 Signal Source, mixed down, input to the remote local oscillator, and used as a reference signal in the Model 1795P Receiver. The RF modulator is activated for the transmit pattern measurements. The compact range feed receives the transmitted RF. Switch 2 (SW 2) is set to position 2 which allows the unused port of the Compact Range feed to be loaded. SW 4 is set to position 2 to route the RF through a directional coupler. The purpose of the attenuator ATTEN 2 is to protect the mixer during transmit pattern measurements. The final switch (SW 3) is set to position 1 to complete the RF path to the Model 1795P Receiver.

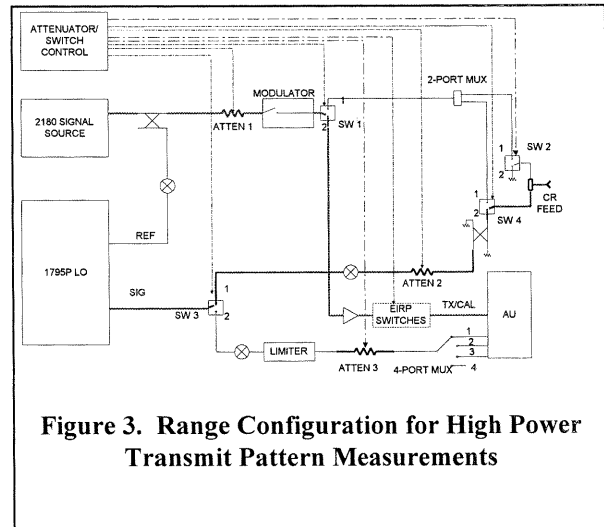


Figure 3. Range Configuration for High Power Transmit Pattern Measurements

2.3 SAFETY

Range safety takes on new meaning in this installation. Personnel safety is assured by the integrity of the chamber as well as operating procedures to restrict access and verification of antenna position and chamber configuration prior to test. Warning lights in the control room and beside the entrance door to the chamber will be activated by Signaal when the high power amplifier is energized. Three video cameras in the chamber will be used to visually check the pointing direction of the antenna under test. In addition, thermocouples will be installed in the area near the high power absorber to detect any warming of the regular absorber near the area protected by high power absorber. Monitoring the temperature rise in the cooling air flow is being considered as another means of determining that the

high power is being directed to the right location so that it may be absorbed as intended.

3.0 IMPLEMENTATION

3.1 HIGH POWER ABSORBER

Ordinary RF absorber will safely absorb up to 0.078 watts/cm² (0.5 watts/inch²). Above that level, special high power absorber must be used. The high power absorber is constructed of honeycomb material which allows air to be circulated through it to remove the heat generated in the material. The chart in Figure 4 is reproduced from data supplied by the absorber vendor.

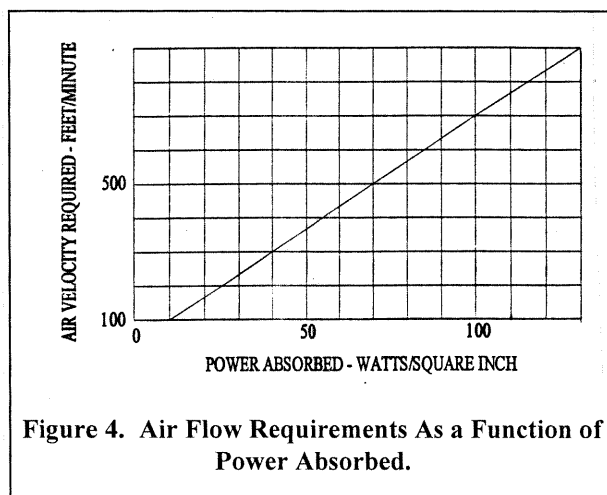


Figure 4. Air Flow Requirements As a Function of Power Absorbed.

3.2 COOLING

The well collimated energy transmitted by the Signal APAR antenna is focused by the compact range optics onto the compact range reflector's focal plane. The focused energy is diffraction limited due to the APAR's finite size. The resulting focal plane diffraction pattern has a prominent main lobe and decreasing, nearly concentric, sidelobes that fall off rapidly.

The high power absorber will be installed in a limited area in the focal plane in order to dissipate the energy in the high intensity region of the diffraction pattern. It will consist of special high power absorber which can absorb in excess of 120 watts per square inch (12.7 dBW/cm²). There are two power levels to consider. Below 0.078 watts/cm² (-11.08 dBW/cm²), ordinary absorber can be used. Above that level, high power absorber with forced air cooling must be used.

Figure 5 shows the average intensity plot of the APAR diffraction pattern at the focus of the compact range

reflector parabola for CW transmission at the lowest operating frequency. Figure 5 is the intensity plot for the case where the antenna positioner is positioned to measure the APAR antenna pattern at the peak of the antenna's main beam. Note the symmetry of the pattern, the high intensity main lobe, and the decreasing sidelobe levels.

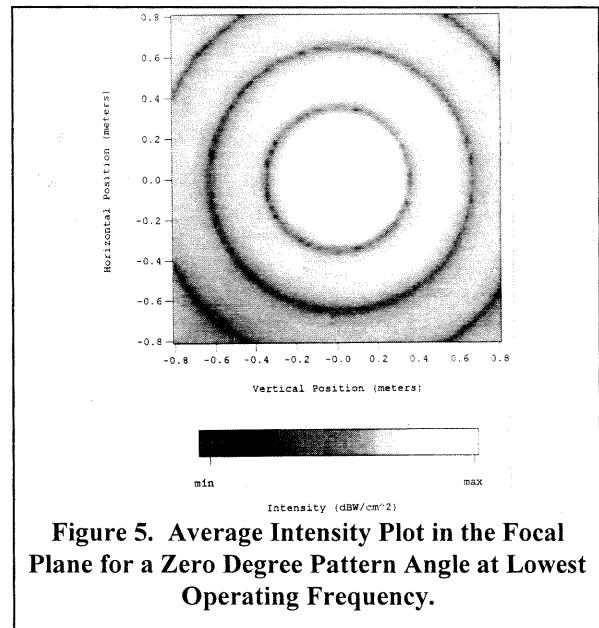
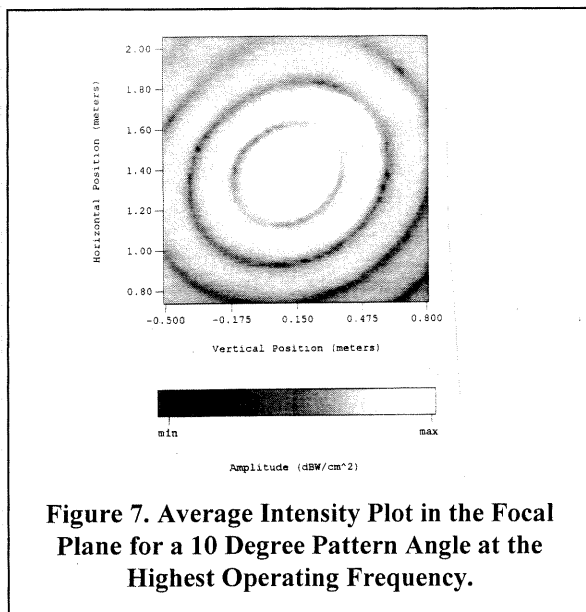
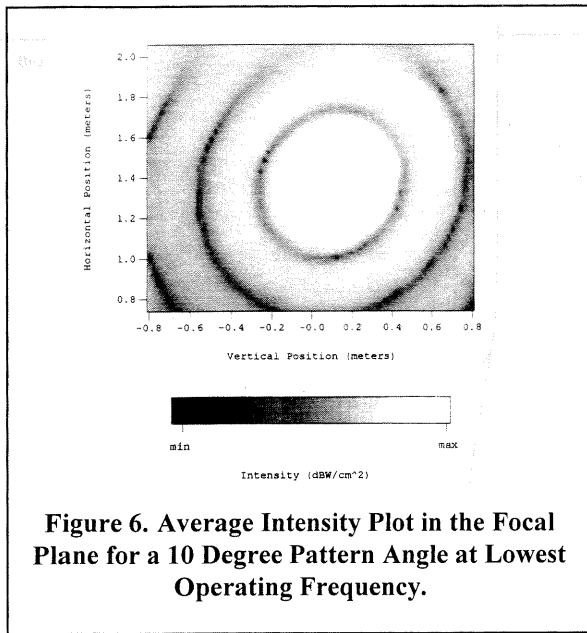


Figure 5. Average Intensity Plot in the Focal Plane for a Zero Degree Pattern Angle at Lowest Operating Frequency.

Figure 6 shows the diffraction pattern average intensity plot at the lowest operating frequency for the case when the azimuth positioner is set to measure the APAR antenna pattern at +10 degrees. Note that the peak of the intensity pattern main lobe has moved laterally approximately 1.4 meters and up approximately 0.1 meters (the upward movement is due to the offset geometry of the compact range optics). Note also that the intensity has dropped due to the energy being spread over a slightly larger region in the focal plane.

At higher frequencies, the energy is concentrated over a smaller area with higher intensities. The size requirement of the air cooled absorber is therefore driven by the intensity distribution at the lowest operating frequency.

Figure 7 illustrates the smaller size of the intensity function at the highest operating frequency for the 10 degree scanned case. The maximum intensities are well below the rating of the high power absorber.



The contour lines at the lowest operating frequency define the region in the focal plane over which the high power absorber must extend. To simplify design and construction, the area of high power absorber will be expanded to the “squared off” shape shown in Figure 2.

From Figure 4, the air flow requirements associated with this incident power density can be determined. The flow area through the absorber is 5.90 square meters (63.5 square feet). The volume of air moving

through the absorber is the product of the velocity times the area.

The power added to the air, q_{added} , raises its temperature. The rise is

$$\Delta t_F = \frac{q_{\text{added}}}{1.08 \left(\frac{\text{min} \cdot \text{BTU}}{\text{ft}^3 \text{ R hr}} \right) Q_{\text{air}}}, \text{ in degrees F.}$$

3.3 HEAT LOAD ON CHAMBER

Post-award consultation with facilities personnel at Signal relative to the entire air conditioning system load determined that the best way to remove the heat from the chamber would be to provide sufficient air flow to handle the load from the high power absorber and the other heat sources. Air is supplied to the chamber behind the reflector and it is extracted through four return air grills near the rear of the chamber. This flow keeps the heated air away from the key elements which might affect the measurement accuracy, namely the test instrumentation, the reflector, the feed positioner, and the antenna under test positioner.

3.4 INTERLOCKS

The APAR antenna will be positioned in the desired location in the quiet zone of the compact range using a motorized slide, the Scientific-Atlanta Model 55450B (M) Azimuth-over-elevation-over-azimuth Positioner and the Model 53450B (M) Roll Positioner. Hardware interlocks which will be employed include adjustable limit switches on the lower azimuth positioner which will be the scan axis for high power transmit tests. The elevation positioner will also be provided with limit switches and hard stops; however, only the lower azimuth limit switches will be reset for each high power transmit scan.

Software interlocks will include the following:

- Rejection of requested electronic beam scans of greater than the steering limits of the APAR.
- Rejection of requested scan axis other than lower azimuth for high power transmit tests.
- Rejection of pulse repetition rate/pulsewidth combinations which result in duty cycles higher than the design duty cycle in the high power transmit tests.
- Rejection of pulse repetition rate/pulsewidth combinations which result in duty cycles leading

to power densities greater than 0.078 watts/cm² in the low power transmit tests (in which the scan beam will be rotated up to ±90 degrees in azimuth from the range centerline and consequently beyond the highpower absorber portion of the absorber fence).

- Rejection of requests for rotation of the lower azimuth greater than ±10 degrees from the electronically scanned beam peak during high power transmit tests.
- Inhibition of RF power to the APAR while frequency is being changed by the 2095 Measurement System.

4.0 SUMMARY

A compact range has been designed for the high power testing of an Active Phased Array Radar

capable of transmitting more than 1 kW average continuous wave power. Software and hardware interlocks will keep the high power energy focused on a region nominally within ±10 degrees of the range centerline and over the area depicted in Figure 2. The RF energy will be captured as heat and dissipated in the chamber as an added load on the HVAC system through the use of high power absorber with forced air convection.

REFERENCES

1. J. S. Hollis, T. J. Lyon, L. Clayton, Jr., Microwave Antenna Measurements, Scientific-Atlanta, Inc., Atlanta, Georgia, USA, 1970.