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**RADIO-FREQUENCY ATTENUATION MEASUREMENTS
ON HIGH ALTITUDE NUCLEAR DETONATIONS**

by

J L Dossey

APRIL 1960

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MEASUREMENTS ON HIGH ALTITUDE NUCLEAR DETONATIONS

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ABSTRACT

Several missile systems depend upon radio-frequency transmission for guidance. Considerable concern is being expressed regarding the effects which very high altitude nuclear detonations might have on such transmission. This paper reports on a system of measurement used to investigate the phenomena during a series of full-scale nuclear tests.

Very simply, Deacon-Arrow II two-stage missiles with nose cones containing transmitters operating at either 225 mc or 1500 mc were positioned appropriately throughout the atmosphere containing a nuclear explosion. Signals received, normalized to the curve representing free-space attenuation as a function of distance, were a measure of attenuation due to ionization versus time and position.

RADIO-FREQUENCY ATTENUATION MEASUREMENTS ON HIGH ALTITUDE NUCLEAR DETONATIONS

Planning and Instrumentation

Several missile and antimissile systems depend wholly upon radio-frequency transmission for guidance. Considerable concern is being expressed about the effects that very high altitude nuclear detonations might have on such transmission. Radio-frequency signals undoubtedly suffer severe attenuation in the highly ionized atmosphere containing a nuclear explosion. Apparent shifts in phase of the transmitted signal, because of refraction, could conceivably result. Radio-frequency effects studies were undertaken by Sandia Corporation in an attempt to measure these effects as a function of distance, frequency, and time.

Method of Measurement

Several methods for making the measurement had been considered. The technique used was based on the establishment of four transmitting stations so spaced at altitude to enable receiving stations to look through the center of the burst as well as through the fringe areas. Each station in space consisted of two missiles, each of which carried a transmitter, one operating at a frequency of about 225 mc, the other at a frequency of about 1500 mc. Two receiving stations were used. Each housed eight receivers, four high-frequency and four low-frequency. An output of each receiver proportional to signal strength of the received signal was recorded on both paper and magnetic tape. The 80-kc intermediate frequency of the low-frequency receivers was directly recorded on magnetic tape to enable detection of large variations in phase. An attempt to measure phase shifts of less than 100 cycles per second was made by first mixing the 80-kc intermediate frequency with a stable and manually adjustable local oscillator before recording on the paper oscillograph. Range of attenuation measurable by the telemetry system was determined to be approximately 55 db at both 225 mc and 1500 mc. Two low-frequency rocket-borne transmitters were tracked by the MIDOT system, primarily to obtain typical trajectory data and, secondarily, to observe signal attenuation and phase disturbance.

Site Geometry

Eight two-stage missiles, either the Deacon-Arrow or the Viper-Arrow combination, were set for launch on each shot. Their launch times were variously related to the missile carrying the warhead. The launch azimuths of the missiles were carefully determined in an attempt to optimize their positions in space, consistent with the following boundary conditions:

1. Line of sight, transmitter stations to receiver stations, must penetrate the center of burst as well as the anticipated fringe areas of total blackout.
2. Minimum 5-degree separation in azimuth between the nearest transmitter missile trajectory and the trajectory of the missile carrying the warhead.
3. Antenna beam widths to half-power points:

225 mc transmitting	80 degrees
1500 mc transmitting	41 degrees
225 mc receiving	42 degrees
1500 mc receiving	26 degrees

Launcher Pads

Eight concrete launcher pads, 6 feet square and 6 inches thick, were constructed along the southern shore of the island location. A small zero-length launcher, mounted on each pad, was used to direct the missiles along the calculated trajectories.

Receiving Stations

One receiving station was located on the island. The other station was located in a trailer on a shipboard installation.

Missile Configuration

The transmitter carrier-missile system* was selected from available components in an attempt to meet the primary requirement of lifting a 10-pound pay load to an altitude of approximately 500,000 feet. The smallest possible rockets were selected to reduce problems of handling and procurement of metal parts.

System Description

A combination of a Deacon booster and an Arrow sustainer was thought capable of satisfying the design requirements. Somewhat inconsistent flight-test data indicated that this system would reach an altitude of only about 300,000 feet. To obtain the desired data at higher altitudes, a combination of a Viper booster and Arrow sustainer was tested, with initial indications of a maximum altitude of about 500,000 feet. Details of both rockets are given in Figure 1.

An adapter section joins the first stage to the second stage. The transmitter canister is attached to the Arrow II with a second adapter section. The nose cone fastens directly to the transmitter canister and contains the second-stage firing circuitry.

*Force, C. T., and Walker, W. E., Design Characteristics and Performance of Sandia's Deacon-Arrow Chaff-Rocket System, SC 4229 (TR), November 1958.

Firing Circuitry

The first stage of both missile systems is fired by direct connection through a safing plug to the master timing circuit and then to a 24-volt battery pack. The Arrow II second stage is fired by the circuit shown in the block diagram of Figure 2. The arm-safe switch is manually actuated before launch. The acceleration switch senses a fraction of missile acceleration and fires the timer squib. The timer runs a preset 22 seconds and fires the second stage, which carries the transmitter canister to the desired altitude at burst time.

Description of Transmitters

Both the 223- to 225-mc and the 1450- to 1500-mc transmitters are packaged in a canister 3-1/2 inches in diameter by 15 inches long. The approximate weight of either package is 9-1/2 pounds. Nickel-cadmium battery power supplies were selected to provide approximately 50 minutes of operation. The transmitter power supply is switched on and off, as required, before launch, by a magnetic holding relay controlled by manually actuated signals. The signals are sent to the transmitter canister through an explosively actuated disconnect plug and cable assembly. Antennas for both the high- and low-frequency transmitters are trailing dipole whips.

Low-Frequency Transmitter

Schematic	See Figure 3
Transmitter	Bendix TXV-13
Frequencies	222 mc, 223 mc, 224 mc, and 225 mc
Power output	2 watts CW, nominal
Modulation	None, grounded grid input
Power requirements	
Filament	18 v DC, 400 ma
Plate	200 v DC, 100 ma
Power source	
Filament	18 v, 500-mah capacity
Plate	200 v, 100-mah capacity
Antenna	Trailing dipole whips, 1/4 wavelength, 45 degrees to missile longitudinal axis
Beam width to half-power points	60 degrees
Gain	4 db

High-Frequency Transmitter

Transmitter	Cavity resonator, tube type 2C39
Frequencies	1450 mc, 1475 mc, 1500 mc, 1525 mc
Power output	2 kilowatts peak, nominal
Modulation	Pulse, 200 cps, 1/2-microsecond pulse width

High Frequency Transmitter (continued)

Power requirements	
Filament	7.2 v DC, 1.0 amp
Plate	2.5 kv, 500 microamps
Power source	
Filament	7.2 v, 1.5-ah capacity
Plate	Transistor power supply, 7.2 v to 2.5 kv, 250-ma input
Antenna	Trailing dipole whips, 3/4 wave-length, 20 degrees to missile longitudinal axis, with reflectors
Beam width to half- power points	41 degrees
Gain	4 db

Receiving Station Description

A block diagram of the two receiving stations is shown in Figure 4. Basically, the transmitted signal is received by a high-gain helical antenna, amplified by an RF amplifier, detected in a receiver, and recorded on both paper oscillographs and magnetic tape recorders. An ASCOP preamplifier and multicoupler are used at 225 mc for amplification and coupling; a traveling-wave tube amplifier is used at 1500 mc. The signal from the cathode of the S-meter tube of the National 300 low-frequency receiver, through a cathode follower, is recorded on a Miller paper oscillograph in parallel with an Ampex 800 magnetic tape recorder. This recorded signal varies in proportion to the received signal. The 80-kc intermediate frequency of the National receiver is recorded directly with the Ampex tape recorder to measure large phase variations in the low-frequency transmitted signal. In measuring phase variation below 100 cps, the 80-kc intermediate frequency is also mixed with a local oscillator, which is stable and manually adjustable, and sent through a cathode follower to the Miller oscillograph for recording. From a difference amplifier at the detector end of the 40-mc intermediate frequency strip in the high-frequency Polarad receivers, a signal proportional to the peak power of the transmitters is fed through a DC amplifier to both the Miller and Ampex recorders.

Low-Frequency Receiving Equipment

Antenna	Helix, 7-turn, 14-db gain, 42-degrees beam width
RF amplifier	ASCOP multicoupler, Model AMC-2, 9-db gain, 9.5-db noise figure
RF preamplifier	ASCOP, Model APA-2, 15-db gain, 2.5-db noise figure
Receiver	National 300, with converter; sensitivity 0.1 microvolt at 50 ohms, 10-db noise figure
Recorders	Miller, paper oscillograph, with 230-cps galvanometers, Ampex 800, with FM recording amplifiers; 13.5-kc center- frequency; direct recorders, 20- to 100-kc response

High-Frequency Receiving Equipment

Antenna	Helix, 7-turn, 15-db gain, 26 degrees beam width
RF amplifier	RCA A-1056 traveling-wave tube, 32-db gain, 7-db noise figure
Receiver	Polarad Model R, sensitivity, minus 80 dbm, 8-db noise figure
Power divider	Admittance, Namco Corporation Model CD-3, 3-db split
Recorders	Miller and Ampex 800

Transmitter Positioning

The Sandia MIDOT system* was used to track the 222-mc and 224-mc transmitter missiles. The MIDOT system functions in a manner similar to the Michelson light interferometer. The high-gain helical antennas, separated a measured number of wavelengths at the received frequency, are fed into a single summing point (T-connector). The single output of the "T" goes to an ASCOP multicoupler, then to Nems-Clarke receiver, and then to a Miller paper oscillograph recorder. A null occurs at the summing point any time a 180-degree phase difference is produced as a result of the difference in arrival time of the RF signal at the two antennas. A mathematical relationship can be derived which relates the angle between the line of sight to the transmitter and the antenna base line to the wavelength of the received frequency, as follows:

$$a = \cos^{-1} \frac{1(K+1/2)\lambda}{D\lambda}$$

where

a = angle between line of sight to the transmitter and the antenna base line when a null occurs

K = an integer

λ = wavelength of received frequency

D = number of wavelengths in the antenna base line

An accuracy of 2 mils in angle in trajectory determination can normally be expected. With the short base lines used at the island location, the accuracy is somewhat less than 2 mils in angle. Accurate placement of two receiving stations each with orthogonal base lines is a minimum requirement. A common time base, 1000 cps, is recorded on the Miller oscillograph simultaneously with the data.

*Pace, T. L., Crawley, T. V., and Hansen, J. W., The MIDOT System, Sandia Corporation Technical Memorandum 76-58(52), December 12, 1958.

System Performance

Six Deacon-Arrow missiles and two Viper-Arrow missiles were fired on one test detonation. The Deacon-Arrow missiles were placed at 100,000 feet at burst time along various azimuths anticipated to bracket the fringe areas of ionization. The Viper-Arrows were dispatched along a predetermined azimuth with the intention of viewing the transmitters through the center of the fireball. Four high- and four low-frequency transmitters were used. Both Viper-Arrows suffered first-stage instabilities and fell to the island prior to burst time. Data were recorded on five of the six transmitters functioning at burst time. The Deacon-Arrow missiles flew in accordance with a predetermined trajectory. MIDOT trajectory data were obtained on the 224-mc transmitter.

Eight Deacon-Arrow missiles were in place for launch on another test detonation. Four were placed approximately at apogee at burst time to permit viewing through the fireball. Two more were on the same trajectory as the first four but were at 98,000 feet at burst time. The remaining two were on the trajectory employed on the initial test, one at apogee at burst time, the other at 117,000 feet on the ascending portion of flight. Four high- and four low-frequency transmitters were used. The 224-mc transmitter was off at burst time as a result of the probable failure of the second stage of the missile to ignite. One high-frequency transmitter was functioning at burst time; two failed before burst; one was not launched because of frequency duplication. Good-quality data were obtained on three low-frequency transmitters. The recorded signal level was very low on the one high-frequency transmitter working at burst time. MIDOT data were obtained on the 222-mc transmitter at apogee behind the burst at zero time.

Security classification of the results preclude their presentation.

WEIGHTS

LAUNCH DEACON BOOSTER	228 LBS
VIPER BOOSTER	270 LBS
SECOND STAGE	41 LBS
NOSE ASSEMBLY	16 LBS

MOTOR SPECIFICATIONS

	A-8 DEACON	VIPER II	ARROW II
THRUST, LBS	6000	8200	2000
IMPULSE, LBS-SEC	18,000	31,100	3800
TIME, SEC	3.0	3.8	1.9
DIAMETER, IN	6.0	6.5	3.0
LENGTH, IN	110.2	106.8	60

Figure 1. Transmitter Missile Characteristics

Figure 2. Arrow II Firing Circuitry

Figure 3. Low-Frequency Transmitter

Figure 4. Receiving Station Diagram