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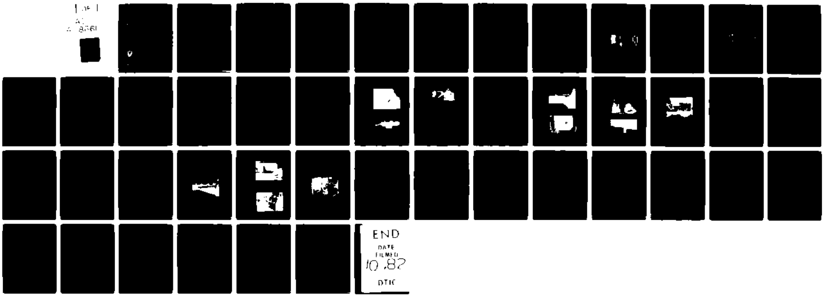

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Technical Report - 81-3

IMPROVED AIRBORNE HF RECEIVE ANTENNA - AN ILIR REPORT - FY-81

JOHN F. BRUNE
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US ARMY AVIONICS R&D ACTIVITY

JULY 1982

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An investigation of improvement of signal-to-noise ratio in an Airborne High Frequency Single Sideband (HF SSB) system by use of an "active," dedicated, receive antenna function, in addition to a combination transmit/receive mode now commonly provided (shorted-loop). The approach described is an optional receive mode of the shorted-loop antenna, where electronic tuning, a stage of RF gain and a stage of matching is provided in lieu of passive tuned function normally provided by the HF SSB amp/coupler. The results obtained in this

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20. ABSTRACT (Contd)

study show a possible improvement of 5 to 10 dB in the signal-to-noise ratio over the passively tuned antenna. This translates in raising an intelligibility reading of a "2" to "5." It is anticipated that this improved sensitivity can provide a doubling of the width of the "window" in some cases. A second advantage is to permit very rapid scanning over a broad range of frequencies within a portion of the 2-30 MHz HF Band while using a "High Q" device. The present shorted-loop design is passively tuned by cumbersome mechanically driven capacitors, thus preventing a rapid receive scan mode.

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1. BACKGROUND

HF communication has been provided in several of the Army aircraft for some time, primarily fixed wing and in the UH-1 (HUEY) for special missions. The use of HF has been used primarily to achieve a long range communication that is beyond the capability provided by FM (30-76 MHz), VHF (116-152 MHz), and UHF (225-400 MHz). Present flight doctrine require aircraft to fly through valleys, behind hills or in defilade to better avoid detection by enemy surveillance radars, while in transit or in an assigned target area. The above standard complement of communications (SLAE) is not satisfactory for nap-of-the-earth (NOE) tactical maneuvers due to the loss of line-of-sight conditions; hence an alternate means was investigated. It was determined that HF when implemented with a specific frequency selection discipline can provide a reliable communication means over a short-range situation that is completely independent of terrain conditions. The HF equipment when used in the modern single sideband (SSB) mode is a part of one of AVRADA's current thrusts: the fielding of an NOE Communications System which will provide an improved means of communication to and from aircraft while flying in a NOE mode. (NOTE: The thrust also includes an Improved FM system (IFM), featuring higher-radiated power via a power amplifier and improved antennas. The IFM will provide improved communications in a near non-line-of-sight condition.)

A commonly recognized problem of including the HF portion of the spectrum, 2 to 30 MHz, on the helicopter is the lack of physical space to place a reasonable near resonant length antenna, especially the lower end of the band (2 to 10 MHz) that is required to support short range skywave propagation. After investigation of numerous antenna "devices," it was concluded (a) that effective radiation at the required frequencies can be achieved by causing the excitation of the entire airframe, and (b) that the best excitation was produced by an antenna concept based upon the unbalanced shorted transmission line principle, now commonly known as the "shorted-loop." The combined transmit-receive function of this antenna has been shown to be practical; however, additional system performance could possibly be achieved by use of a dedicated receive mode.

2. OBJECTIVES

The objective of this research program was to determine what feasible performance improvement might be obtained in an airborne HF system, by use of a separate, optimized receive antenna in addition to that antenna used in a dual transmit/receive function. The principal thrust is to demonstrate improved signal-to-noise ratio which will result in increased sensitivity thus permitting a greater latitude of a workable frequency choice.

3. APPROACH

a. The program was begun by a literature search, in order to determine some of the techniques that have been examined by others to achieve an efficient, non-resonant antenna over the frequency range of 2 to 30 MHz, particular emphasis was placed on these efforts within the 2 to 10 MHz frequency band. Some of the short antenna techniques considered were the ferrite loop, small multi-turn loop, voltage probe, and current probe. However, as a result of recent significant advance in the solid-state technology of high frequency (low noise) devices, the major effort in this study was centered on an active-antenna approach.

TABLE 1. FEED POINT IMPEDANCE - SHORTED LOOP

LOOP LENGTH 14' 9" AIRCRAFT LENGTH 40' 6"

FREQ MHz	R	±j	FREQ	R	±j
2	0.2	+53	17	31	-348
3	0.31	+81	18	20	-308
4	0.48	+113	19	14	-247
5	1.13	+150	20	11	-200
6	3.92	+198	21	9.3	-160
7	11.87	+252	22	8.2	-125
8	21.6	+322	23	7	-94
9	34	+425	24	6	-65
10	43	+600	25	5.3	-37
11	50	+959	26	4.6	-9
12	336	+2124	26.3	4.5	±0
*12.813	10020		27	5.5	+21
13	4684	-5202	28	9.3	+53
14	262	-1233	29	15.5	+86
15	138	-783	30	21	+132
16	65.8	-536			

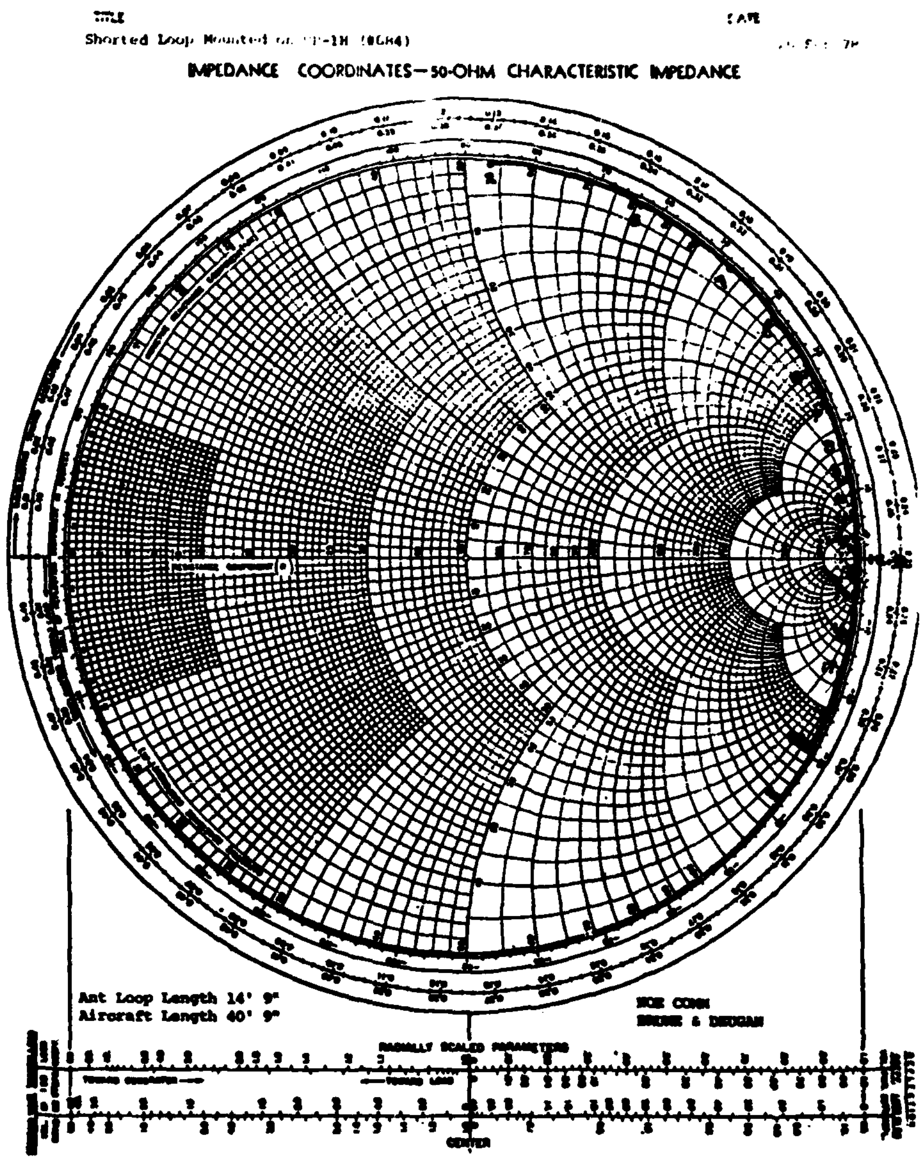


Figure 1. Shorted loop mounted on UH-1H (#684)

TABLE 2. FEED POINT IMPEDANCE - SIMULATED SHORTED LOOP

FREQ MHz	MAG	ANGLE	R	j	FREQ MHz	MAG	ANGLE	R	j
2.0	22	+90	+0.04	22	14.0	1.8K	-90	-343	-1800
3,0	32	+90	+0.06	+32	15.0	620	-90	-380	-620
4.0	45	+90	+0.086	+45	16	380	-90	-280	-380
4.5	52	+90	+0.10	+52	17	280	-90	-220	-280
5	60	+90	+0.50	+60	18	220	-90	-220	-220
6	76	+90	+1.5	+76	19	180	-90	-160	-180
7	100	+90	+2.0	+100	20	160	-90	-140	-20160
8	120	+90	+5.2	+120	21	140	-90	-120	-140
9.0	160	+90	+15.2	+160	22	120	-90	-110	-120
10.0	220	+90	+23.2	+220	23	110	-90	-+72.9	-110
11.0	320	+90	+32.4	+320	28	72	-90	-14	-72
12.5	850	+90	+162	850	30	62	-90	-11.8	-62
13.5	450K	0	4500	0					

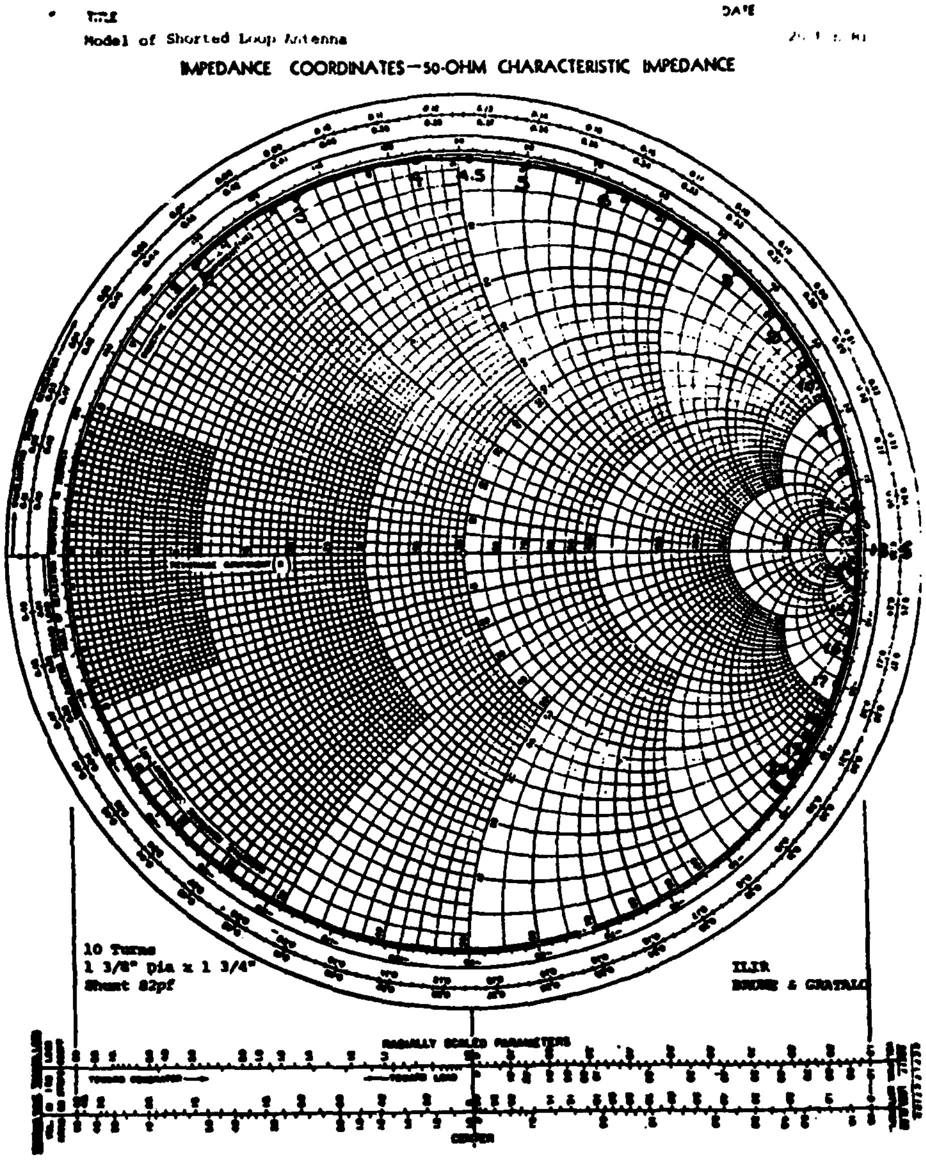


Figure 2. Model of shorted loop antenna

b. Several commercial firms have already invested considerable research effort in the field of development of a practical active antenna in the VLF, LF, and HF areas. This study provided a suitable source for the acquisition of a commercial device that can be evaluated in the airborne environment, along with an in-house laboratory developed approach.

c. It was determined that the in-house laboratory development should center on providing the electronics to form an "active" shorted-loop. Namely, this antenna has already been chosen as the basic antenna to be installed on the helicopter-type aircraft and thus a switch function could be incorporated to distinguish between a "dedicated" receive function and the dual purpose transmit/receive application.

d. A survey was conducted to determine the best available solid-state devices to be acquired for the construction of an amplifier for the shorted-loop antenna. The input-impedance of this device is predominately inductive reactance and with low values of resistance over the 2 to 10-MHz range of frequencies. The assistance of the Electronic Devices and Technology Laboratory was solicited, resulting in a suggestion of an approach using a Field Effects Transistor (FET) as a matching/amplifier device.

4. DESIGN DETAILS

a. As indicated above, the objective was to examine the "active" approach as applied to a voltage-probe type and then to the same "shorted-loop" as now used in a passive transmit/receive mode. It was determined to buy the voltage-probe type and to design and build the current probe-type in house.

An active voltage probe-type antenna was purchased from Bayshore Systems Corporation, Model UPS-192, detailed specifications as provided in the appendix.

b. The impedance characteristic of the shorted-loop antenna as installed on a UH-1H helicopter is shown in Table 1. NOTE: The form of the impedance plot shown in Figure 1 is truly that of a nearly pure inductor. An equivalent, working model of the shorted-loop antenna on the helicopter was designed and built from the impedance plot. This consisted of a loop of ten turns of No. 12 gauge wire with a coil length of 1-3/4 inch and a diameter of 1-3/8 inch and which was shunted with an 82 PF fixed capacitor (Figure 3A). The tabular impedance characteristic is shown in Table 2 and is plotted in Figure 2. Thus, it is evident that the resemblance is close to the actual antenna and was considered to be satisfactory for the purpose of laboratory bench tests to be performed in the development of the "active" matcher/amplifier. A duplicate coil-capacitor was constructed and mounted exterior to a small shielded metal box. Two variable capacitors were arranged in the box as a "T" matcher as shown in Figure 3B. This provides a simulation of the shorted-loop along with that of the coupler that is normally a part of the output amplifier/coupler, typically employed in a HF SSB system. This simulation, however, is equivalent to a receive mode only, i.e., high voltage, power capacitors were not used. The latter arrangement provides a base of reference of a passive tuned antenna model, suitable for laboratory comparisons. Some typical values that were used for matching are shown in Table 3.

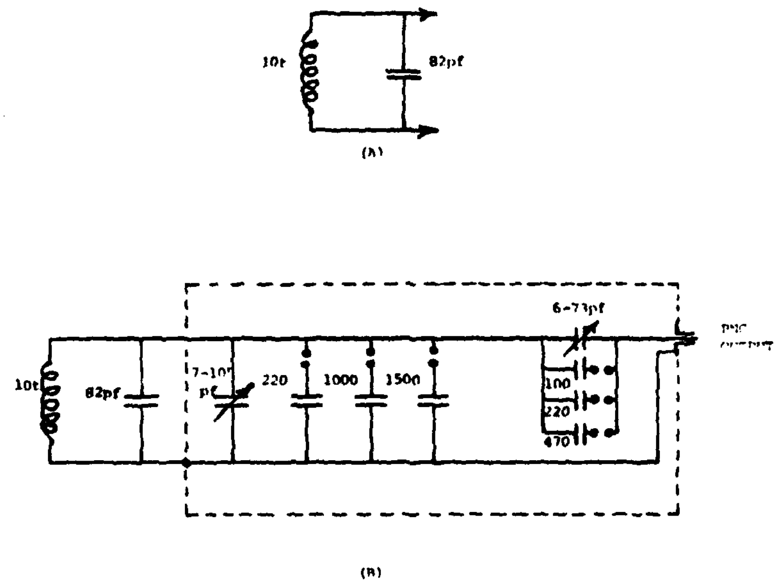


Figure 3. Simulated antenna

TABLE 3. IMPEDANCE AND TYPICAL TUNING OF SIMULATED ANTENNA

FREQUENCY	PARALLEL CAP PF	SERIES CAP PF	IMPEDANCE OHMS
13.561	--	--	450K $\angle 0^\circ$
13.561	--	9	50 $\angle 0^\circ$
6.800	227	30	50 $\angle 0^\circ$
4.779	696	149	50 $\angle 0^\circ$
2.100	2780	497	50 $\angle 0^\circ$

c. A RCA type 3N140, Dual Gate FET was chosen as the amplifying stage. This device is characterized as having a high input impedance, i.e., 50 to 300 K ohms. It is useful with frequencies up to 300 MHz; however, the available published characteristics were provided at a test frequency of 200 MHz. Some of these are as follows:

(1) Power Gain --------------- 18 dB

(2) Noise Figure ------------- 3.5 dB

(3) Forward Transconductance -- 10,000 μ mhos

(4) Input Capacitance --------- 5.5 pf

The required frequency range in this application was only 2 to 10 MHz and the power gain proved to be up to 40 dB, in some select cases.

d. The approach chosen was to provide only parallel capacitance across the antennas at designated frequencies lower than the frequency of self-resonance (13.5 MHz). The addition of the appropriate amount of parallel capacitance will produce resonance at a chosen frequency, i.e., a high resistance without reactance, thus an appropriate feed for the high impedance FET. There is no need to translate the high resistance to 50 ohms, as in the case of typical RF devices. In this instance where the FET is used, a 50-ohm input would be very inefficient.

e. Variable and fixed capacitors were used across the input, that is, in shunt with the coil and gate 1 of the 3N140 in the initial feasibility design (Figure 4). In addition to the feature of a high input impedance of this FET, an impedance transformation to approximately 300 ohms is provided across the output; that is, across the "drain" and "sink." The major purpose of the second gate of the 3N140 is to provide a variable gain. Gate 2 was provided with a variable bias accessable by a screw adjustable 100 K ohm potentiometer. A design for the additional required impedance transformation of 300 to 50 ohms was tested using a tapped coil as shown in Figure 4.

f. In the next phase of the development, the use of varicaps in lieu of the manual capacitors was examined. A type MST-125 varicap was obtained and examined on a "Q" meter. The typical variation of capacitance versus voltage is shown in Table 4. The capacitance was found to vary from 266 PF at 0 volts to 55 PF with 28 volts applied. The varicap approach was then incorporated into the circuit as shown in Figure 5. The tuning capability of several combinations were examined in the "active" mode and the results are shown in Table 5.

g. The output matcher (300 to 50 Ω) using a tapped coil, was frequency sensitive due to an LC circuit formed by the lower "L" tap and the coupling capacitor "C." A common collector or emitter follower was designed and built using a general purpose 2N2222 transistor as shown in Figure 6. An almost perfect and flat (in respect to frequency) matcher, was obtained when this approach was used in lieu of the tapped coil.

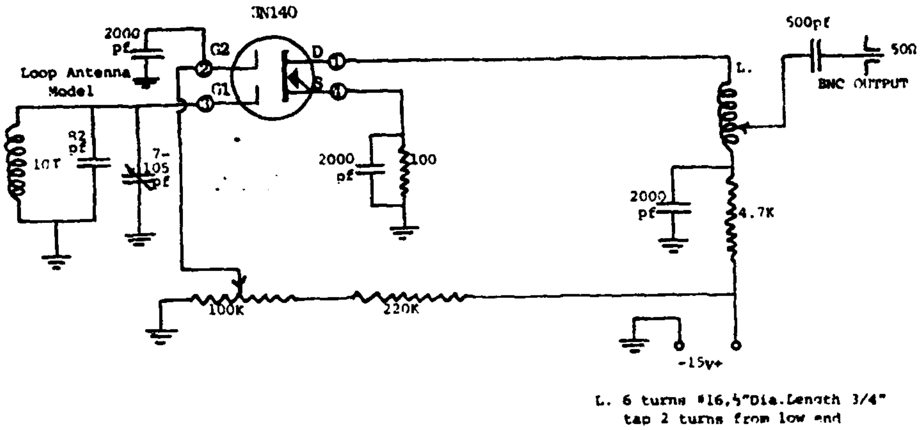


Figure 4. Matching amplifier for Shorted loop antenna

TABLE 4. VOLTAGE - CAPACITANCE CHARACTERISTICS

VARICAP MSI TYPE 125

E	pF	E	pF
28V	55	6	109
25V	60	4	127
20	64	3	142
18	68	2	164
16	72	1	204
14	76	.5	241
12	80	.25	255
10	87	0	266
8	96		

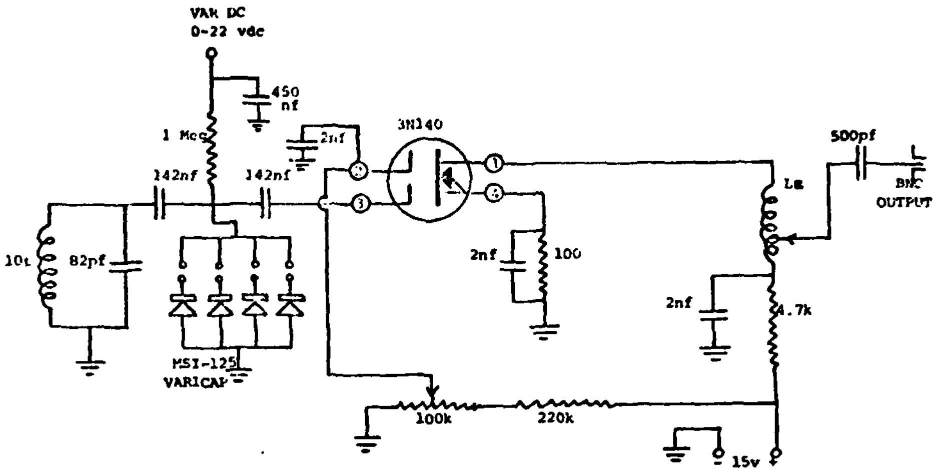


Figure 5. Antenna tuning with varicaps

TABLE 5. VARICAP MSI-125 VOLTAGE - FREQUENCY CHARACTERISTIC WITH SIMULATED ANTENNA

Ec	FREQ MHz	Ec	FREQ MHz	Ec	FREQ MHz	Ec	FREQ MHz
				ONE EACH			
0.04	5.825	0.75	6.515	5.0	7.965	17.50	9.044
0.10	5.898	1.0	6.632	7.50	8.345	20.00	9.165
0.20	6.018	1.0	6.632	7.50	8.849	22.50	9.263
0.30	6.125	2.0	7.136	10.00	8.547	27.50	9.425
0.40	6.214	3.0	7.483	12.50	8.754	0	5.762
0.50	6.315	4.0	7.50	15.00	8.196		
				TWO EACH			
0	4.372	0.25	4.649	2.5	5.802	15.0	7.516
0.05	4.434	0.50	4.859	5.0	6.441	20.0	7.826
0.10	4.497	1.0	5.199	10.0	7.107	27.5	8.161
				THREE EACH			
0	3.701	0.25	3.940	2.5	4.989	15.0	6.633
0.06	3.767	0.50	4.125	5.0	5.584	20.0	6.954
0.10	3.807	1.0	4.434	10.0	6.220	27.5	7.309
				FOUR EACH			
0	3.268	0.25	3.487	2.5	4.011	15.0	6.009
0.07	3.342	0.50	3.650	5.0	4.462	20.0	6.321
0.1	3.363	1.0	3.937	10.0	5.607	27.5	6.682
				NONE			
0	11.46						

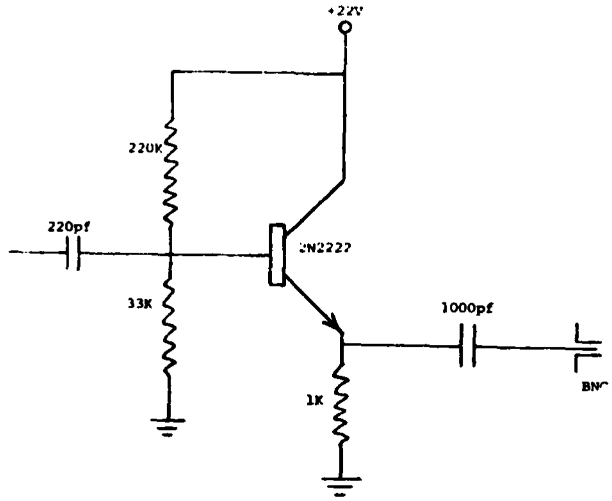
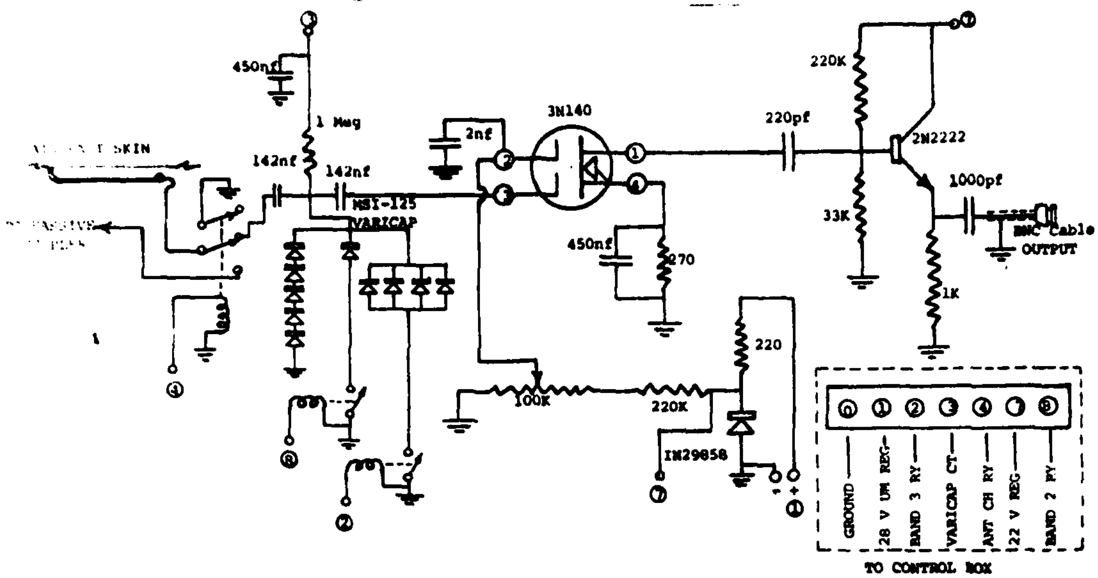


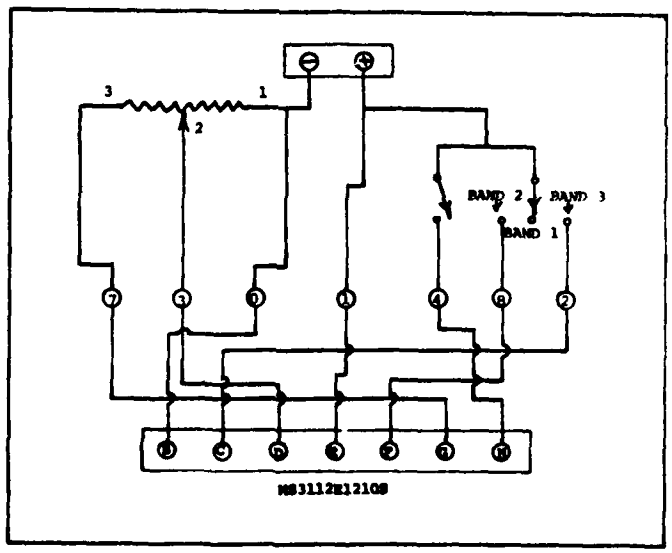
Figure 6. Emitter follower impedance matcher

h. With the decision to tune with varicaps, it was then obvious that a voltage control capability was required. This was devised using a 1N2985B zener and a suitable series resistor. Refering back to subparagraph f and Table 5, it was necessary to choose various combinations of varicaps to cover the desired frequency range of 2.5 to 8.5 MHz. A single varicap was found to be satisfactory for the "high" band when using the 10 turn coil; however, later when the active device was attached to the real antennas, less capacitance was required to tune the highest required frequency, hence several varicaps were connected in series. This is shown in the schematic of the final flyable model (Figure 7A and B). Three combinations were required to cover the frequency range. The five series varicaps remain connected for all bands while one of two relays provide paralleling to achieve progressively greater capacity as the frequency is lowered, i.e., Band "2" and Band "3."

i. The flyable model of the device consisted of mounting all components, including the change-over relay in a 2 by 4-inch mini-box and suspending same in the open gap or feed point of the shorted-loop antennas (Figure 8). The placement of some of the components can be seen in Figure 9. The circular section to the left of the box is a fiberglass cylinder serving as a RF insulator and provided with brass fittings and an internal lead connects to the change-over relay. A brass tube was used on the opposite side (right side in photo) to extend the ground of the airframe to the mini-box. A front view of the control box is shown in Figure 10. This box contains a precision 10 turn potentiometer (with appropriate dial), used for biasing the varicaps, a band select relay control switch and the antenna change-over relay control switch.



A - Final "flyable" design



B - Control box

Figure 7. Schematics of final flyable model

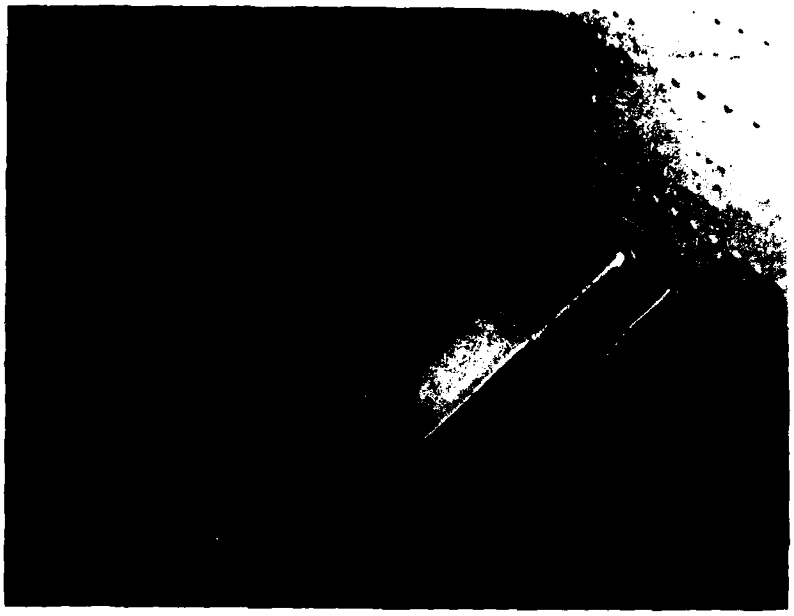


Figure 8. Active device configured to antenna

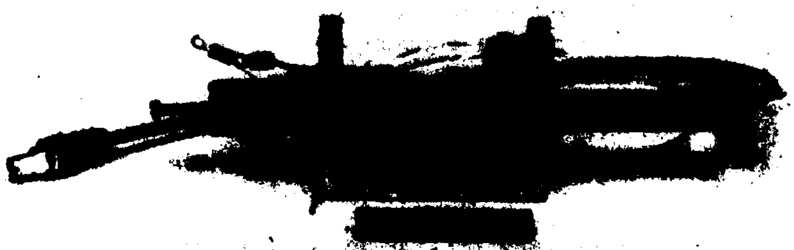


Figure 9. Component placement

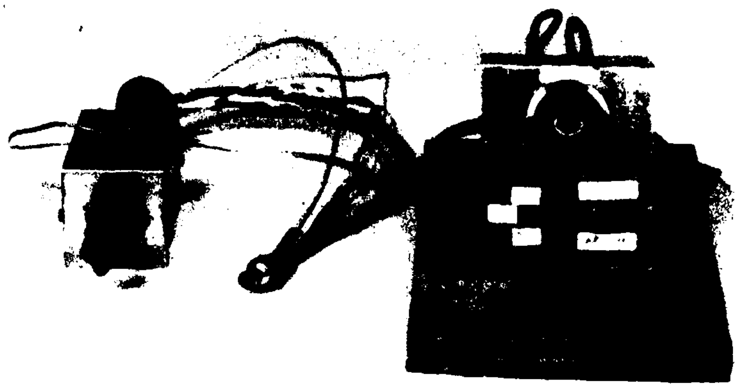


Figure 10. Active device and control box

5. GROUND-TO-GROUND TESTS

a. Procedure.

(1) A mock-up, consisting of the empty shell of an actual UH-1B helicopter was positioned on a 30-foot high, turntable tower at the CECOM Antenna Test Site, Wayside. A 10-foot long shorted-loop antenna, as used in earlier experiments, was first mounted on the tail boom and its impedance characteristic was measured. Then a 16-foot long antenna was mounted and measured. The test results are shown in Table 6. The most significant characteristics noted between the two versions were in a lower magnitude of inductive reactance at the low end of the band for the shorter antenna and a lower self-resonance frequency for the larger antennas. The 16-foot version of the shorted-loop antenna was chosen because less capacitance would be required for matching, in that this capacitance would be obtained by paralleling of relatively small number of variactors. In addition, the self-resonance frequency of 13.10 MHz is above the frequency band of interest in this experiment. The 16-foot shorted-loop antenna and the active device as mounted on the mock-up is shown in Figure 11.

(2) A transmitting site located at a distance of 5400 feet was selected. An adjustable length, resonant dipole, suspended at a height of 30 feet was provided at this site. A similar dipole was provided within a 200 foot distance to the turntable site and used as a reference during gain measurements.

(3) The passively tuned antenna case, which is normally provided by an automatic coupler of a typical HF SSB set was simulated by providing a manually operated coupler, positioned in the same location as the automatic within the boom section of the UH-1H (Figure 12). For data recording purposes, this arrangement was designated as antenna "X."

TABLE 6. FEED POINT IMPEDANCE - SHORTED LOOP

MOCK-UP, UH-1B HULL

10 FT LENGTH			16 FT LENGTH		
FREQ	MAGNITUDE	ANGLE	FREQ	MAGNITUDE	ANGLE
2	34	+84		56	+88
4	68	+88		110	+88
6	108	+88		205	+88
8	155	+88		295	+88
10	205	+87		590	+79
12	274	+86		1550	+68
14	380	+87	13.1	5500	±0
16	585	+86	14	1880	-73
18	1070	+84	16	560	-86
20	4350	+62	18	310	-87
20.6	8800	±0	20	190	-88
22	1950	-74	22	112	-88
24	845	-80	24	54	-85
26	525	-82	26	4.5	±0
28	380	-84	26.5	14	+72
30	278	-86	28	54	+84
			30	120	+86

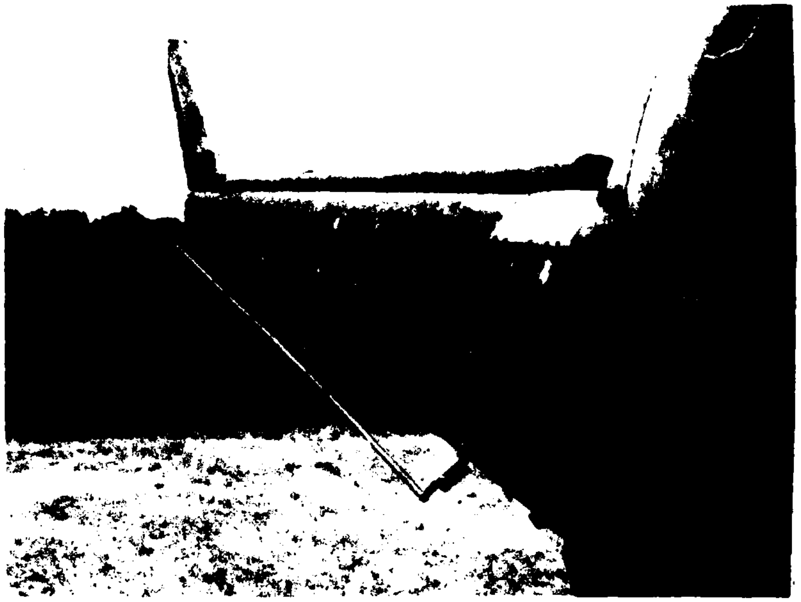


Figure 11. Active device mounted on mock-up

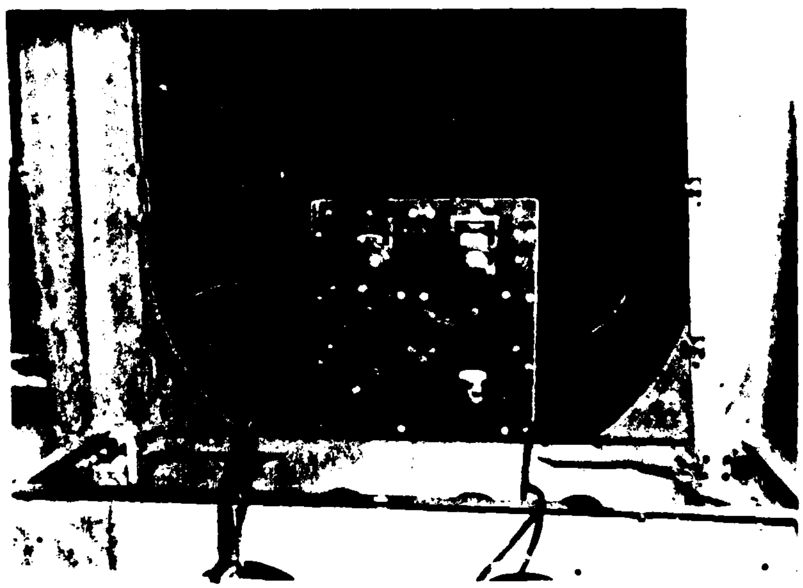


Figure 12. Passive antenna coupler in mock-up

(4) The lab-built, active-type antenna was designated as antenna "Y." The change-over relay provided the choice between active "Y" or the passive "X" with "Y" being connected to the loop in the de-energized position.

(5) The commercial, active-type antenna (Bayshore model UPS-192, Figure 13), was designated as antenna "Z." The voltage-probe blade was mounted on the top of the cockpit section of the mock-up as shown in Figure 14, with the distribution amplifier being placed in the cockpit section.

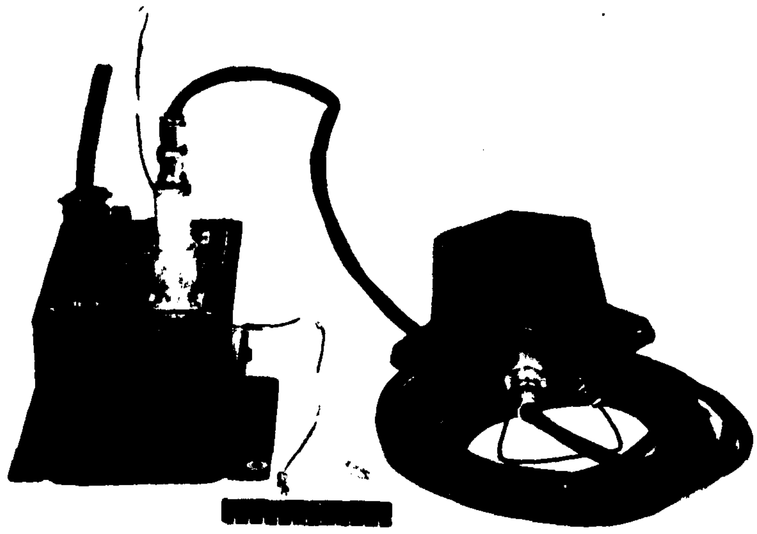


Figure 13. Bayshore UPS-192A active antenna system

Figure 14. UPS-192 voltage-probe mounted on mock-up

(6) A Singer Model NM-25T Noise and Field Intensity meter was used to measure the output of all three antennas during all ground-to-ground tests and the ensuing airborne tests that will be described in section 6. This instrument provides the capability of a readout in terms of microvolts or dB referenced to 1 microvolt of any small signal that is discernible on the modern HF SSB set, i.e., -20 dB/UV or 0.1 UV. This instrument is shown in Figure 15, along with the control box of Antenna "Y" and the distribution amplifier of Antenna "Z." The output cables from antennas "X," "Y," and "Z" are also shown in this photo.

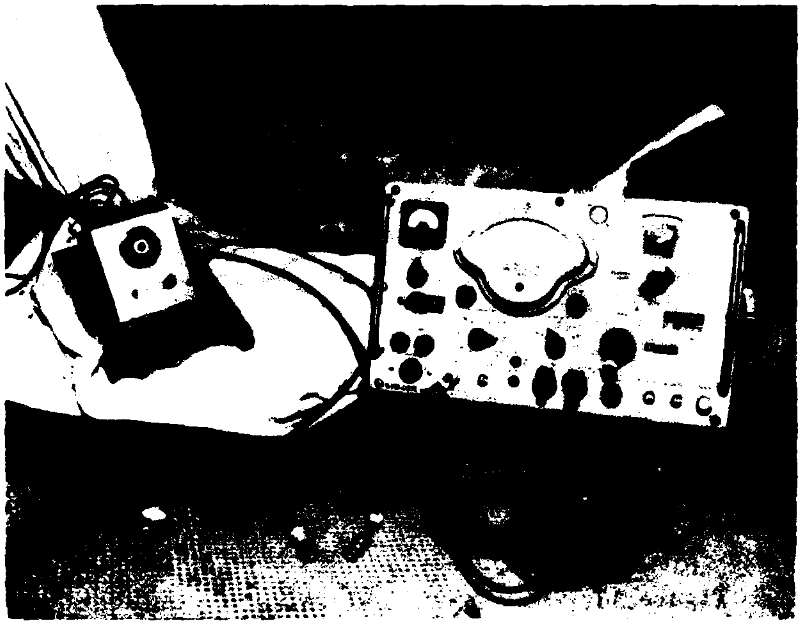


Figure 15. Control and instrumentation as used in mock-up

(7) A comparative gain test was conducted by transmission from a second test site located 5,400 feet away, using a Logimetrics 920 signal generator. An output of +20 dBm (100 mW) was fed into a resonant dipole for each frequency step, ranging from 3.195 to 8.160 MHz. The output of the X, Y, and Z antennas and an adjusted dipole at the receive end were measured with the NM-25T and recorded as shown in Table 7. The signal-off, ambient noise level was read and recorded concurrently with the respective test signals. This data is also shown in Table 7. A graph showing the relative output from each of the four antennas is shown in Figure 16.

TABLE 7. COMPARATIVE GAIN

FREQ MHz	dB/uv							
	PASSIVE		ACTIVE		ACTIVE (B)		DIPOLE	
	X	X_N	Y	Y_N	Z	Z_N	D	D_N
3.195	6	-15	50	25	8	9	18	-7
3.50	9	-12	48	27	10	7	17	-1
4.030	6	-12	45	25	9	5	14	0
4.50	9	-12	46	26	10	5	14	-8
4.910	10	-16	47	25	8	4	13	-7
5.485	14	-16	49	23	15	5	17	-12
5.960	15	-12	50	25	17	5	23	-10
6.500	16	-10	51	30	19	5	25	-8
7.000	24	-5	50	30	21	7	27	-10
7.353	25	-5	—	—	—	-	22	-13
7.609	25	-5	52	30	24	6	27	-10
8.160	25	-5	55	30	21	6	26	-5

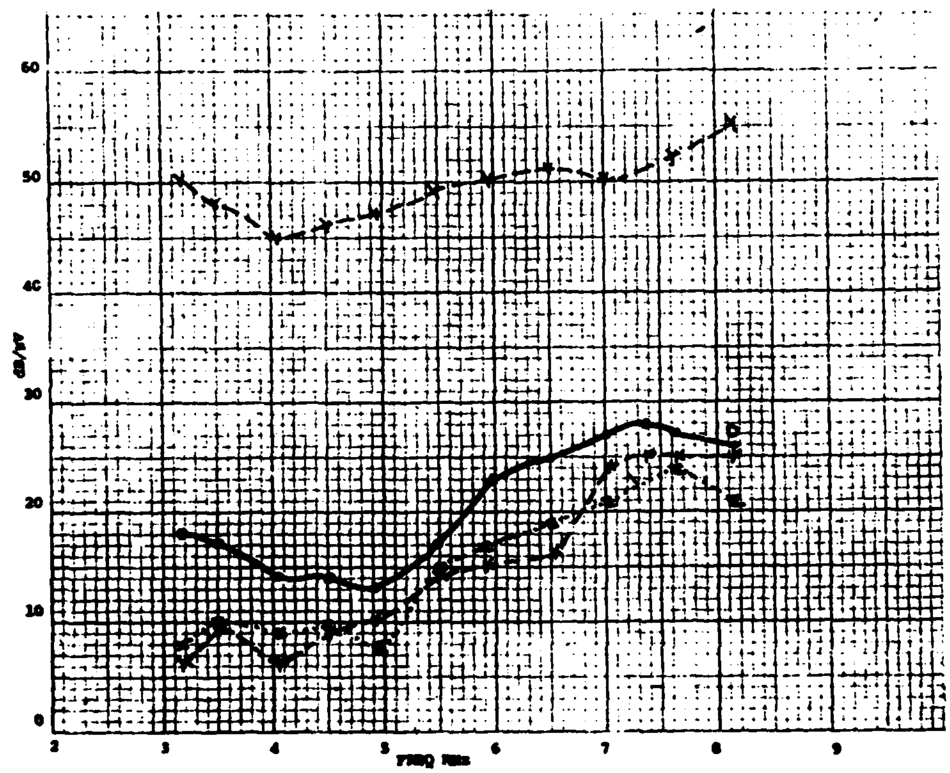


Figure 16. Comparative gain

(8) A comparative minimum discernibility test was conducted by use of the Rec/Trans unit of the AN/GRC-106 Radio Set on each end of the test path. One of the R/Ts was used in a normal HF SSB transmit mode. The output of the R/T had an average power of a 400 mW and this was fed to the input of the adjusted transmit dipole, through a step attenuator. The second R/T was used in a normal receive mode at the mock-up site and its input was connected successively to the output of antennas X, Y, and Z. The transmit level of the R/T was initially adjusted to a minimum discernible level as determined at the receive R/T when connected to the output of the passive antenna X. This value of attenuation became the basis of comparison for the two active antennas as these were connected to the input of the R/T and the transmit signal adjusted to regain the same intelligibility value, namely a "3" to "4" rating (Table 8 and Figure 17).

TABLE 8. HF SSB CIRCUIT
MINIMUM DISCERNIBILITY

FREQ MHz	TRANSMITTER				
	ATTENUATION			ADVANTAGE	
	X	Y	Z	Y-X	Z-X
2.500	15	25	15	10	0
3.195	30	37	25	7	-5
3.500	30	35	20	5	-10
4.031	30	37	15	7	-15
4.910	25	29	15	4	-10
5.500					
5.960	35	43	15	8	-20
6.470	30	37	15	7	-15
7.000					
7.360	30	38	20	8	-10
7.600					
8.160	30	34	23	4	-7

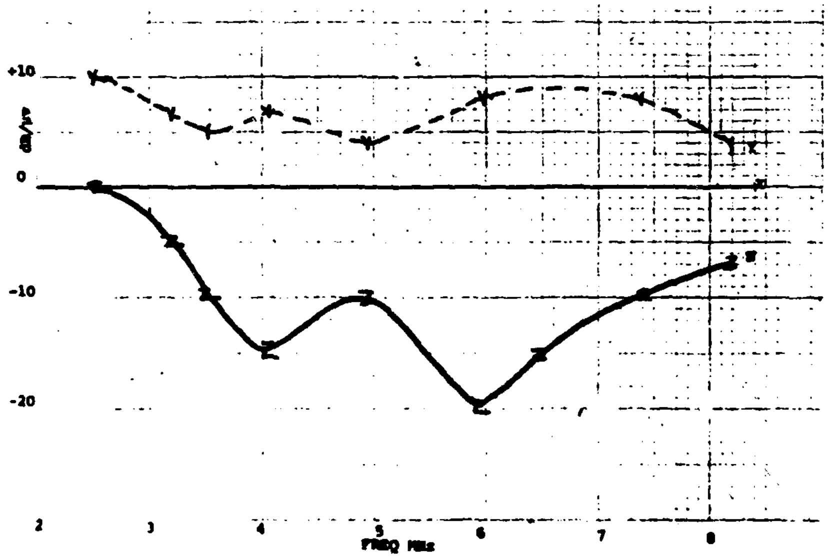


Figure 17. Discernibility as related to passive "X" using HF SSB speech

(9) A quantitative evaluation of signal discernibility was performed by use of a narrow-band 1000 Hz amplifier/meter that is contained within a conventional VSWR meter (HP 415E) normally used as an indicator with a slotted transmission-line set-up. In use, the Logimetrics 920 signal generator was again used as the signal source and modulated at 80 percent using its internal modulation feature. As in (8) above, the output of the passive antenna X was established as the base of reference for the performance of antennas Y and Z. A convenient level of field strength was chosen as read on the NM-25T. The audio output (accessible by a jack connector) was fed into the HP 415E, VSWR meter and the meter controls were adjusted for a mid-scale indication, i.e., "3." Next, the output of antennas Y and Z were fed into the receiving system, in succession, and the transmit power, P_T, was adjusted to the point where the half-scale output from the VSWR meter was re-established. The resulting data in respect to received field strength and adjusted P_T is shown in Table 9. A graph showing the discernibility of antennas Y and Z as normalized to antenna X is shown in Figure 18. (<u>NOTE</u>: This comparison was limited to 8.16 MHz for the Y antenna, due to its matching limitations). The characteristics of the Z antenna, compared to the X antenna was continued to 30 MHz, the upper band edge. Additional comparative gain data were generated in this test, as shown in Table 9, and these results were plotted as a graph, shown in Figure 19.

TABLE 9. RELATIVE DISCERNIBILITY
REFERENCE MODULATION

FREQ MHz	PASSIVE (X)			ACTIVE (Y)			ACTIVE (Z)		
	Fs dB/µv	Audio Level 1000 Hz	Pt dBm	Fs db/µv	Audio Level 1000 Hz	Pt dBm	Fs db/µv	Audio Level 1000Hz	Pt dBm
2.50	-6	3	+20	48 42	2.4 3	+20 -6	30 22	2.5 3	+20 -8
3.195	4	3	+10	45 33	1.4 3	+10 -12	30 19	1.8 3	+10 -11
4.030	14	3	+10	46 35	1.3 3	+10 -11	24 19	1.7 3	+10 -5
4.910	12	3	+10	47 33	1.1 3	+10 -16	20 16	2 3	+10 -4
5.960	21	3	+10	56 36	1.7 3	+10 -20	20 21	3.6 3	+10 +1
6.47	14	3	+10	49 32	1.8 3	+10 -17	18 17	2.8 3	+10 -1
7.36	21	3	+10	52 40	1.4 3	+10 -12	30 23	1.6 3	+10 -7
8.16	17	3	+10	47 34	1.3 3	+10 -13	21 19	2.7 3	+10 -2
12.060	30	3	+20				34 32	2.5 3	+20 -2
16.00	5	3	+20				23 15	1.5 3	+20 -8
20.10	8	3	+20				15 13	2.5 3	+20 -2
24.090	23	3	+20				32 20	1.5 3	+20 -8
30.00 Smith	8 27	3 3	+20 +20				40 26	1.1 3	+20 -14

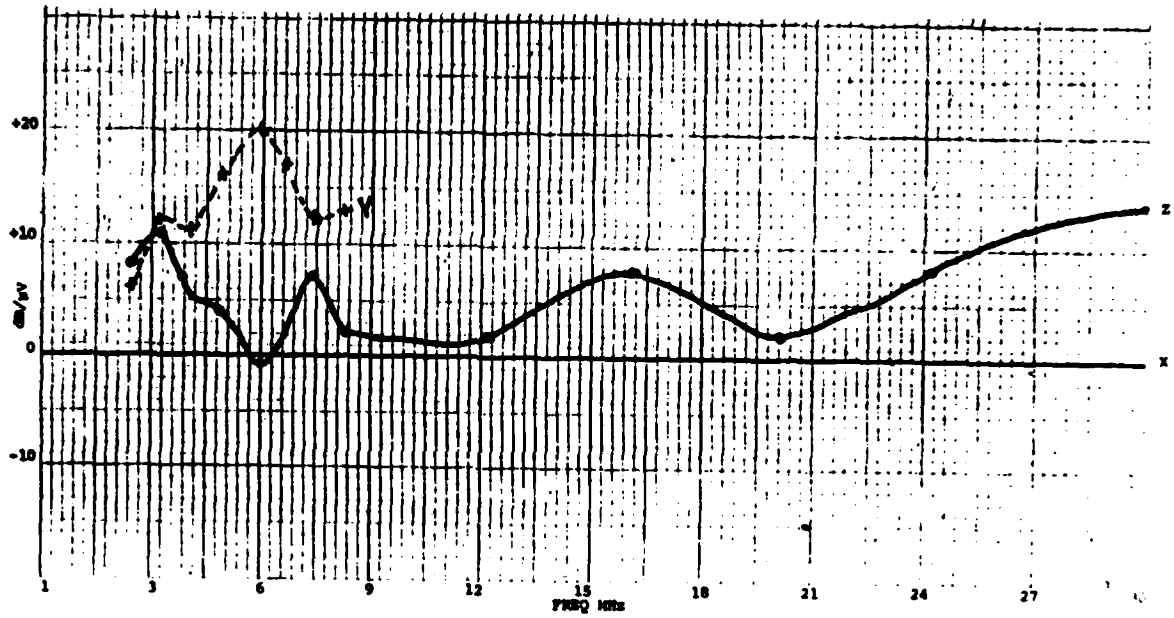


Figure 18. Discernibility as related to passive "X" using 1000 Hz modulation

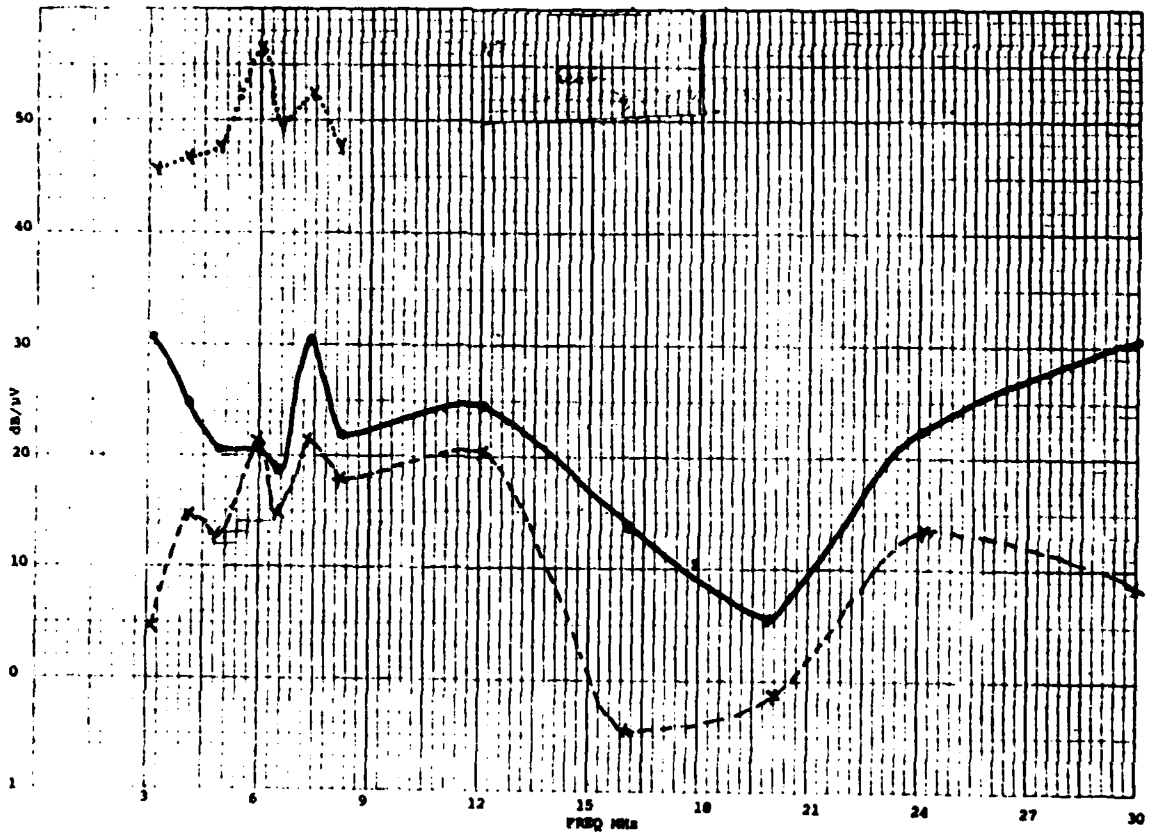


Figure 19. Comparative gain as related to 1000 Hz modulation test

b. Discussion.

(1) A differential of 30 to 40 dB advantage of antenna Y over X is clearly illustrated in Figure 16. However, a portion of this increase is due to amplified ambient atmosphere noise.

(2) The relationship of the resonant dipole to the X antennas as depicted in Figure 16 is considered to be an approximation, due to limited data collected for this element in these tests; i.e., prior experience has shown that the data points obtained at 4.5, 4.910, and 5.485 are probably 3 to 5 dB greater than the data which was recorded. The shorted-loop, 15-foot long antenna, when mounted on the UH-1H, is expected to have a gain characteristic of 10 to 5 dB less than a resonant dipole over the 2 to 6 MHz portion of the HF band.

(3) The gain characteristic of the Z antenna (Bayshore UPS 192A) was shown to be comparable to the X antenna.

(4) The objective of the minimum discernible test was to simulate a weak signal path condition in order to evaluate any improvement that might be provided using either of the active antennas Y or Z in lieu of the normal passive antenna X. The receiver/exciter of an actual HF SSB radio set was used in order to gain any advantage as provided by SSB in the presence of atmospheric noise. The results as shown in Table 8 indicate that a P_T of less than one-half milliwatt was used in most portions of the test where the active antenna Y was being used to feed the R/T at the receive end of the circuit. When the active antenna Z was used, removal of attenuation was required at the transmit end to regain the same level of intelligibility as established by use of the X antenna. The response shows that antenna Z was from 0 to -12 dB less in performance than antenna X (Figure 17). This is attributed for the most part to an inherent noise level within the Z antenna system when operated at a low signal level.

(5) The purpose of the next test was to evaluate the relative merits of the quality of outputs provided by each of the active antennas as compared to the passive type, i.e., signal-to-noise ratio. A fixed modulation frequency, 1000 Hz and a narrow-band filter amplifier was chosen as the discriminator between a signal and intermeshed noise. The results shown by the graph of Figure 18 indicates that the Y antenna has an average of 12 dB improvement of S/N ratio over X, with a peak of 20 dB at a frequency of 5.960 MHz. The Z antenna was found to have an average S/N ratio of 5 dB over the frequency range of 3 to 24 MHz over X, with a peak of 14 dB at 30 MHz.

(6) The plot of the gain characteristic data, shown in Figure 19, indicates a reasonable agreement of antenna Y over X with data recorded in Table 7. However, the performance of the Z antenna is greater for the most part. Then, in the comparison to X above 8.16 MHz, the limit of tuning of antenna Y, a significant improvement of upwards to 5 dB was realized even with a 22 dB advantage over X at a frequency of 30 MHz.

c. Conclusions.

(1) The active antenna "Y" provides a definite advantage over the passive antenna "X" in respect to an increase of field strength, or greater than 30 dB.

(2) The "Y" antenna shows a capability of improving discernibility of intelligibility over "X" by a factor of 5 to 10 dB. This is accomplished by providing amplification directly at the feed point of the antenna, plus providing a signal-to-noise advantage.

(3) As a by-product, it has been demonstrated that the characteristically high "Q," narrow-band shorted-loop antenna can be tuned by a voltage controlled capacitor (varicap). This would permit very rapid scanning over a broad range of frequencies with a portion of the 2-30 MHz HF Band, with the application of appropriate "stair-step" voltages. The present shorted-loop "X" antenna is passively tuned by cumbersome mechanically driven capacitors, thus preventing a rapid receive scan mode.

6. GROUND-TO-AIR TESTS

a. Procedure.

(1) The active assembly that comprises antenna Y, was fortified against vibration by covering the components board with RTV compound. Exterior joints of the box were sealed with RTV and then the device was securely attached across the open end of a normal shorted-loop antenna, as had been installed on an operational UH-1H helicopter, tail No. 6660894. The complete external installation is shown in Figure 20.

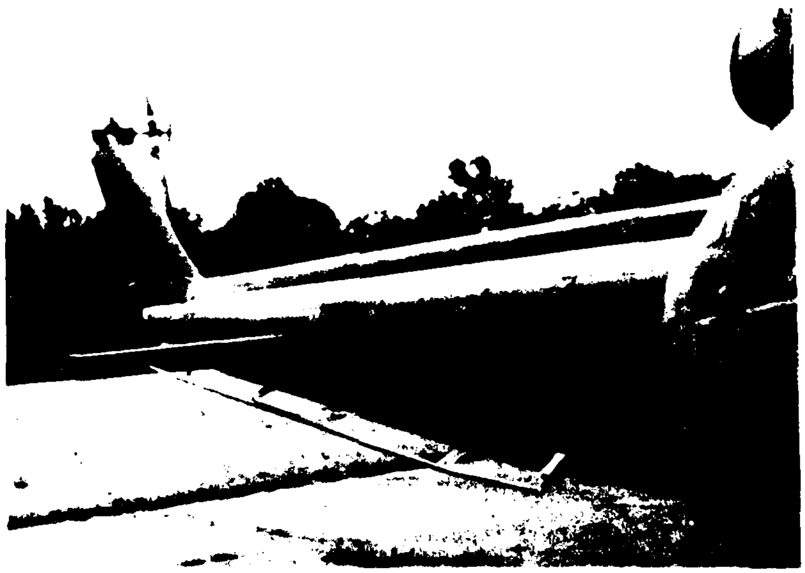


Figure 20. Active device installed on a flyable UH-1H helicopter

(2) The Receiver-Exciter of the AN/ARC-174, 672U, was installed in the portside rear equipment compartment, normally used for the mounting of the AN/ARC-102 (Figure 21). The amplifier/couper, 548S, along with an auxiliary capacitor, 641D, was installed in the space at the beginning of the boom section as normally used for mounting the 490T (CU-1650) antenna coupler (a part of the AN/ARC-102). The set control head, 514A, was installed in the lowest left space of the center console.

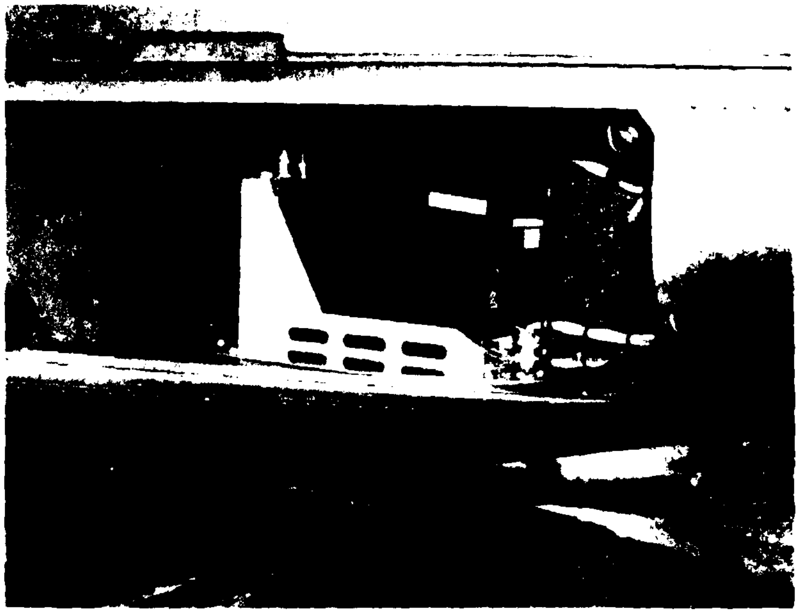


Figure 21. AN/ARC-174 rec/trans installed in the AN/ARC-102 compartment

(3) The Singer NM25T field strength meter and the control head for antenna Y were mounted on an available rack that had been used in a previous project. This rack was already provided with mounting hardware that permitted attachment to the deck of the crew compartment, via seat anchor points. The distribution amplifier of the Bayshore UPS-192A was attached above the map case on the center console. This installation is shown in Figure 22.

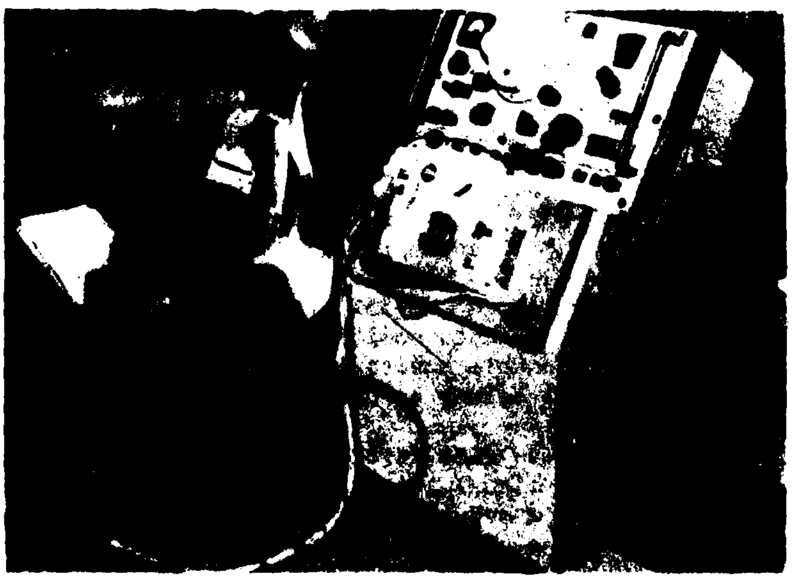


Figure 22. Control and instrumentation as first installed in the crew compartment

(4) The various signal modes, necessary for the conduct of the test, were initially provided by three short length RG-58 cables, terminated with female BNC connectors. These are described as the output of the passive antenna "X" which was a cable connection to a "Tee" connector between the AN/ARC-174 Rec/Exc and the amp/coupler, the output of the active antenna "Y" and the output of the active antenna "Z." The test procedure required measuring the output amplitude of each of the antennas X, Y, and Z on an individual basis in respect to field strength on the NM-25T, then to evaluate the effectiveness of the outputs of antennas "Y" and "Z" in the improvement of intelligibility when incorporated into the major HF SSB communication link, i.e., connecting the "Y" or "Z" antennas output to the input of the R/T of the SSB set while operating in the receive mode.

(5) A marked improvement on the part of the efficiency of the operator was provided by installation of two, electrically operated, coaxial switches, as shown in Figure 23. This improvement was installed before the final comprehensive flight test, as conducted on 2 September 1981.

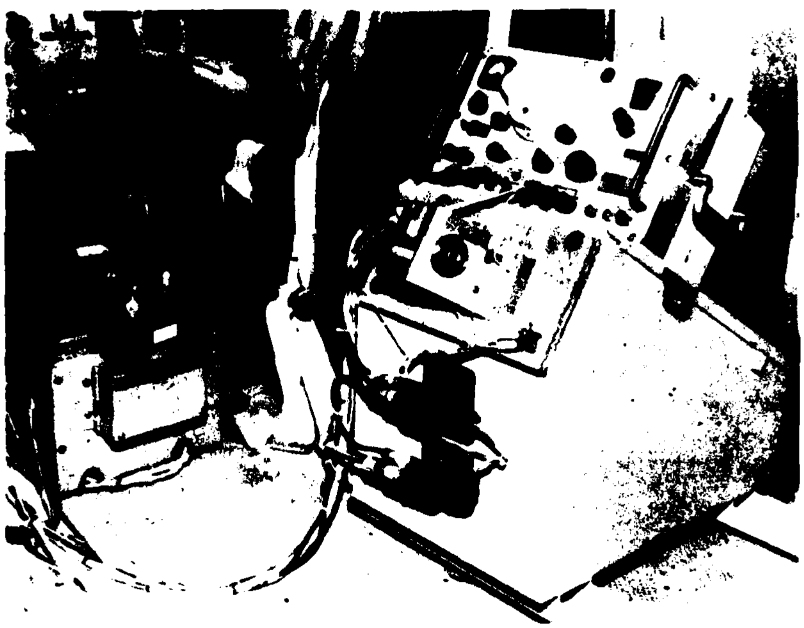


Figure 23. Control and instrumentation as an improved installation

(6) The audio output of the NM-25T field strength meter was interconnected, via a selectable switch, into position No. 4 of the aircraft's interphone system. This was done to enable monitoring and identification of the desired signal by use of the normal helmet earphones.

(7) The installation as made in the flyable helicopter, was checked by the use of the Logimetrics signal generator, fed into a vehicular FM band whip, located with the hanger of a separation distance of approximately 200 feet. The relative field strengths of the X, Y, and Z antennas are shown in Table 10A and plotted as a graph (Figure 24). The relative characteristics of these antennas when operating in a Near Vertical Incident Skywave (NVIS) mode was examined on the following day and these results can be seen in Table 10B and Figure 25.

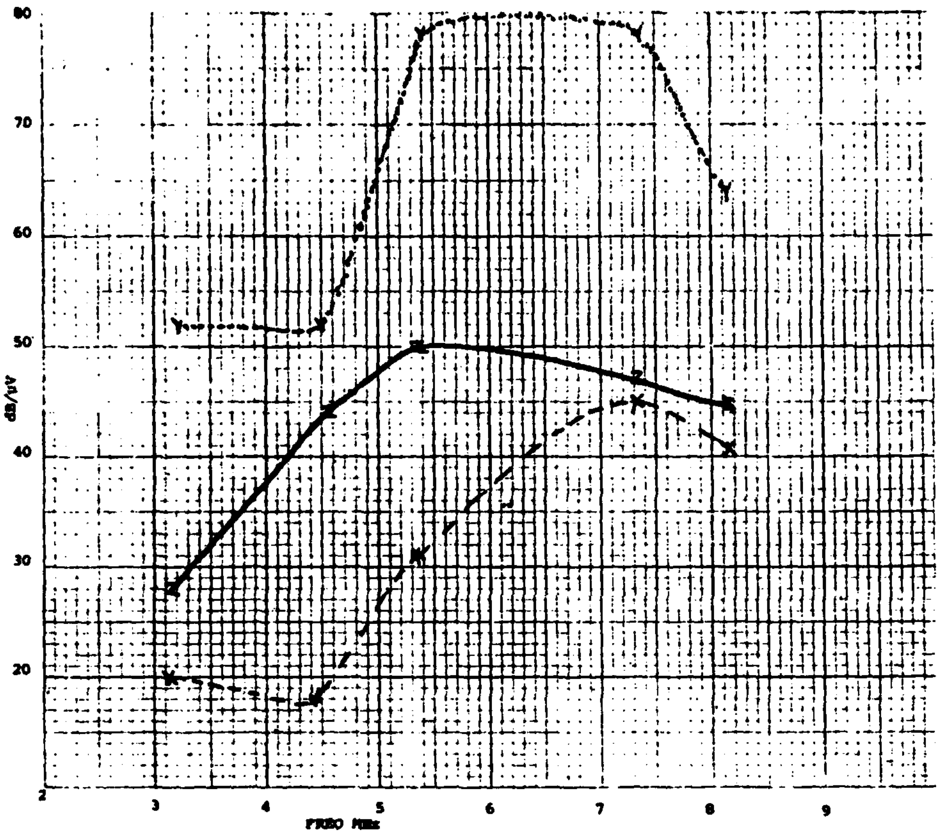


Figure 24. Relative sensitivity

TABLE 10. RELATIVE SENSITIVITY

A					B					
FREQUENCY		WITHIN HANGER FIELD STRENGTH dB/uv			ON FLIGHT LINE					
					X		Y		Z	
CH	MHz	X	Y	Z	db/uv	I	db/uv	I	db/uv	I
1										
2										
3										
4	3.195	20	51	28						
5	4.445	18	51	28	8 15	3 4	35 45	4 5	9 15	2-H 3-V
6	4.927	31	65	44	10	3	40	4	15	3-H
7	5.397	23	78	50	8	4	40	3	5	3-H
8	7.360	45	78	47						
9	8.160	41	64	45						

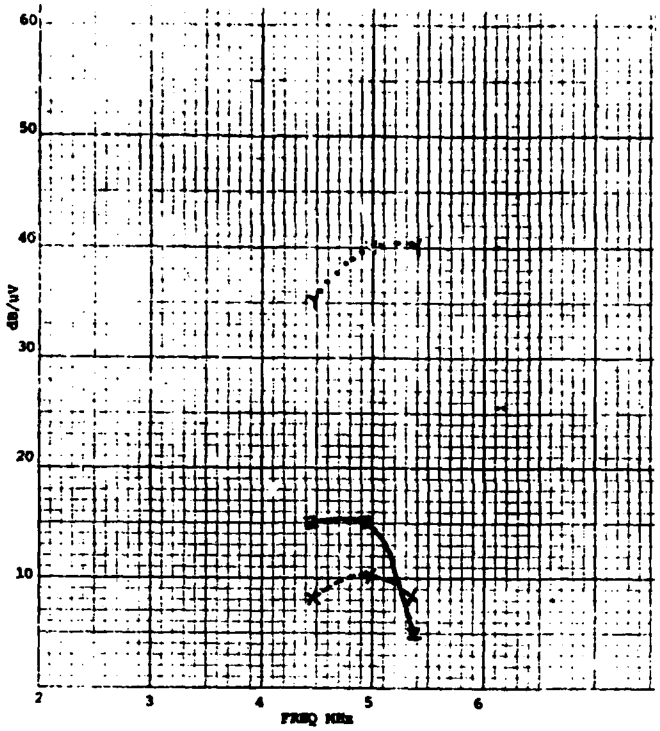


Figure 25. Relative performance - NVIS mode Wayside

(8) A ground and an airborne test was conducted using the passive "X" and active "Z" antennas, without the active "Y" antenna. This was done primarily as a "trouble-shooting" technique in resolving an antenna changeover relay malfunction, as contained within the box inclosure of the "Y" antenna system. The flight was from LAS to Coyle VOR and on to Atlantic City. The results are shown in Tables 11 and 12 and the data in the form of a graph is shown in Figure 26A, B, and C.

TABLE 11. PREFLIGHT - WAYSIDE TO LAS

CH		PASSIVE	ACTIVE
1	2020		
2	2320		
3	2764	21	9
4	3195	20	14
5	4445	16	20
6	4927	21	21
7	5397	14	17
8	7360	27	30
9	8160	28	31
10	12060		

TABLE 12. AIRBORNE TEST

FREQUENCY		X		Z		LOCATION
CH	MHz	db/μv	I	db/μv	I	
5	4.445	10	3	7	3	Flight to Coyle departing
6	4.927	21	4	6	2	1 Mile E. Coyle - 550 feet
6	4.927	9	3	6	2	Touchdown Coyle
5	4.445	10	3	7	2-3	Touchdown Coyle
7	5.397	16	3-4	11	3	Touchdown Coyle
7	5.397	23	4	11	3	800 feet underway to Atlantic City
8	7.360	24	4-5	6	2	5 miles from Atlantic City
9	8.160	23	4	11	3	Hover at Atlantic City
9	8.160	18	3-4	12	3	Touchdown Atlantic City
5	4.445	8	3	4	2	Touchdown Atlantic City
7	5.397	26	4-5	12	3	20 miles from Atlantic City (return)

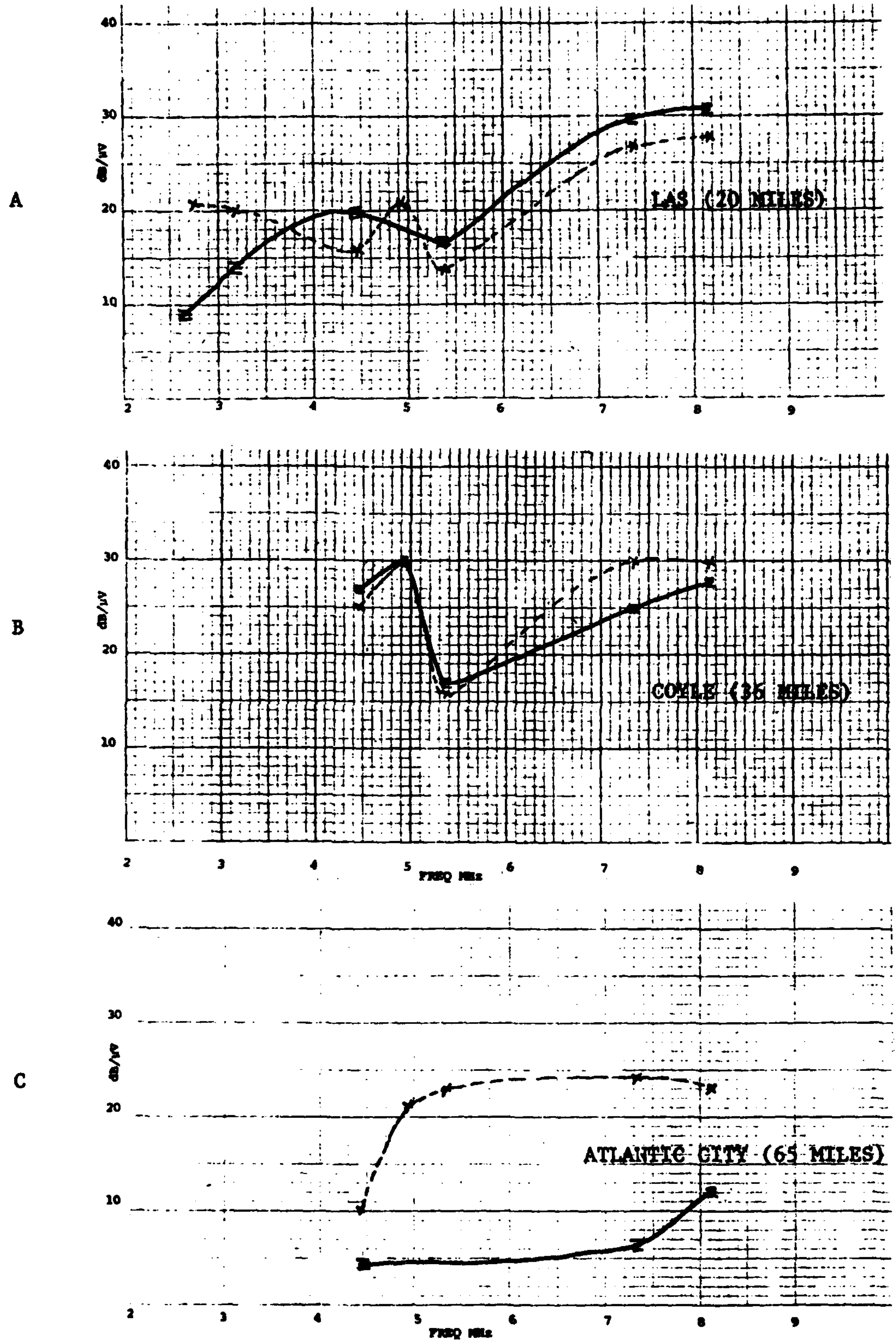


Figure 26. Relative performance - 26 Aug 81 - NVIS mode

(9) Subsequent to the redesign of the installation of the antenna changeover relay (a necessary function to permit the choice between the passive "X" transmit/receive mode and the receive active "Y" mode), a second set of tests of sensitivity were performed using a procedure similar to step (7) above, while the aircraft was inside the hanger. This data is shown in Table 13 and Figure 27.

TABLE 13. RELATIVE SENSITIVITY

FREQUENCY		X		Y		Z	
CH	MHz	db/μv	I	db/μv	I	db/μv	I
3	2.764	3	1	27	4	19	3
4	3.195	2	1	20	3	13	2
5	4.445	7	2	31	5	19	4
6	4.927	30	5	59	5	39	5
7	5.397	27	5	56	5	45	5
8	7.360	54	5	70	5	57	5
9	8.160	51	5	66	5	47	5

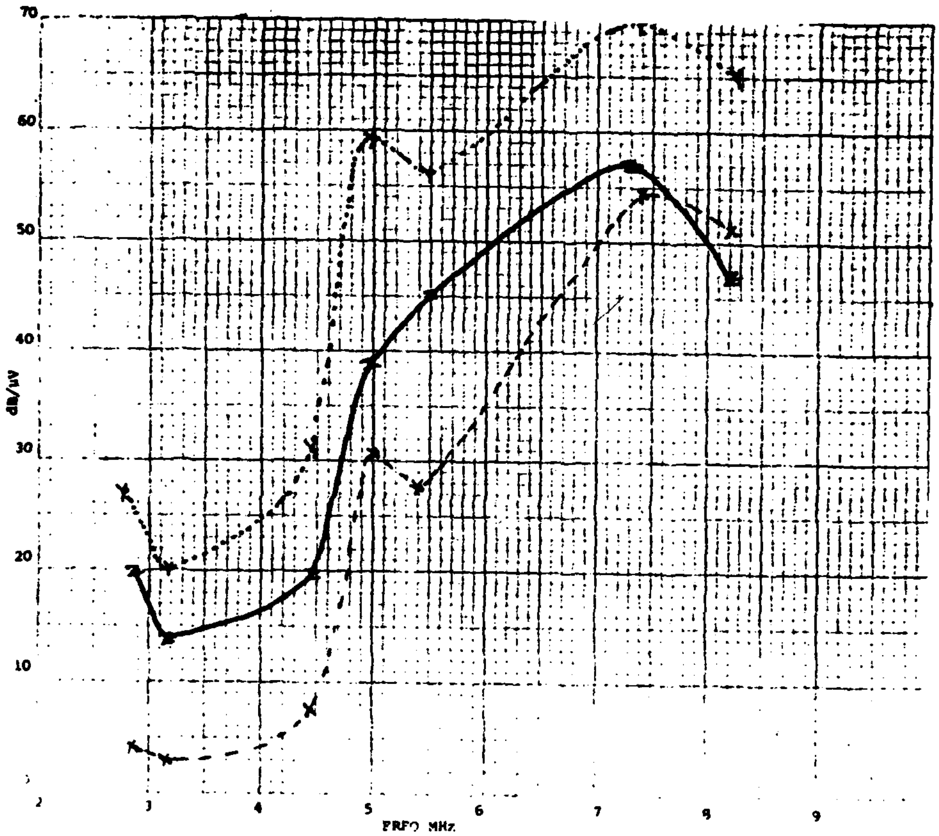


Figure 27. Relative sensitivity

(10) The aircraft was then moved to the flight line (out of the hanger) and the relative response characteristics of the three antennas were examined under NVIS conditions. This was accomplished by establishment of a communication path to the Wayside site, a ground distance of 20 miles, but with an NVIS radio path of approximately 375 miles. (NOTE: The round trip path length to the ionized layers and return, a loss equal to about 10 miles ground wave loss.) The results of these measurements are shown in Table 14 and plotted as a graph (Figure 28).

TABLE 14. WAYSIDE TO FLIGHT LINE LAS

FREQUENCY		X		Y		Z	
CH	MHz	db/μv	I	db/μv	I	db/μv	I
3	2.764	-3	0	18	4	10	2
4	3.195	0	4	20	4	3	1
5	4.445	23	5	48	5	21	5
6	4.927	20	5	38	5	18	4
7	5.397	15	4	45	5	12	3
8	7.360	23	4-5	35	5	12	3
9	8.160	30	5	44	5	27	5

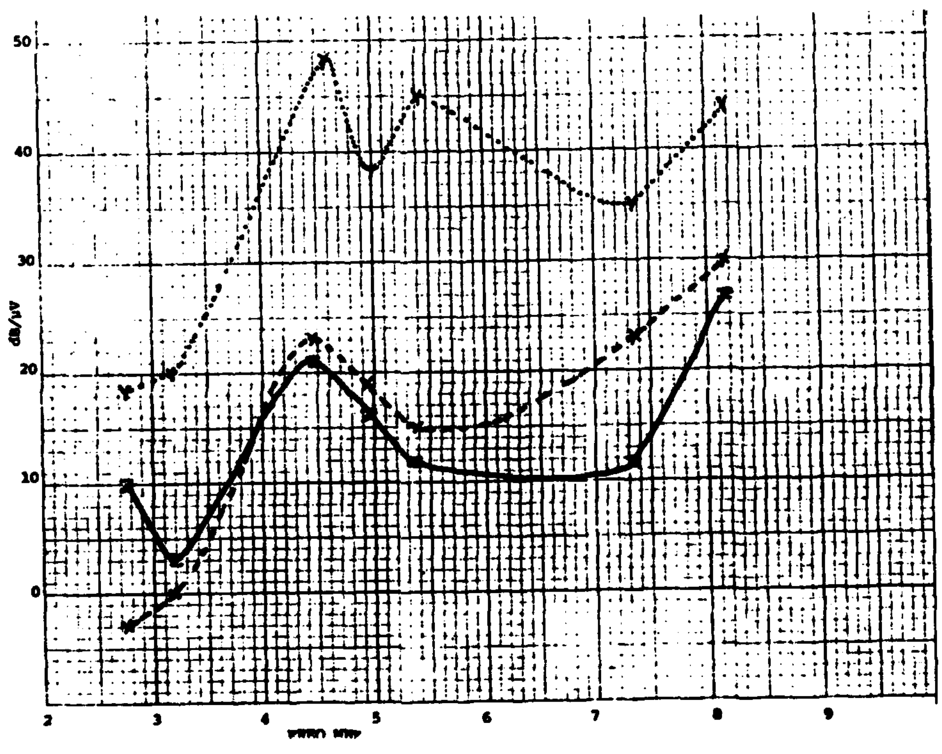


Figure 28. Relative characteristic - Wayside to flight line LAS - 28 Aug 81 - 0815 - 1140 dipole XMIT

(11) The transmission from the Wayside site was performed using a resonant dipole as recorded in (10) above, and then a mobile-vehicular version of the shorted-loop was used as the transmitting source. The results of this test is provided in Table 15 and Figure 29.

TABLE 15. RELATIVE CHARACTERISTIC - WAYSIDE (MOBILE) TO LAS

FREQUENCY		X		Y		Z	
CH	MHz	db/μv	I	db/μv	I	db/μv	I
5	4.445	5	0	16	2	5	0
6	4.927	6	1-2	32	4	7	1-2
7	5.397	10	2	35	4	4	1
8	7.360	16	3	36	4	10	2
9	8.160	12	2	32	4	10	2

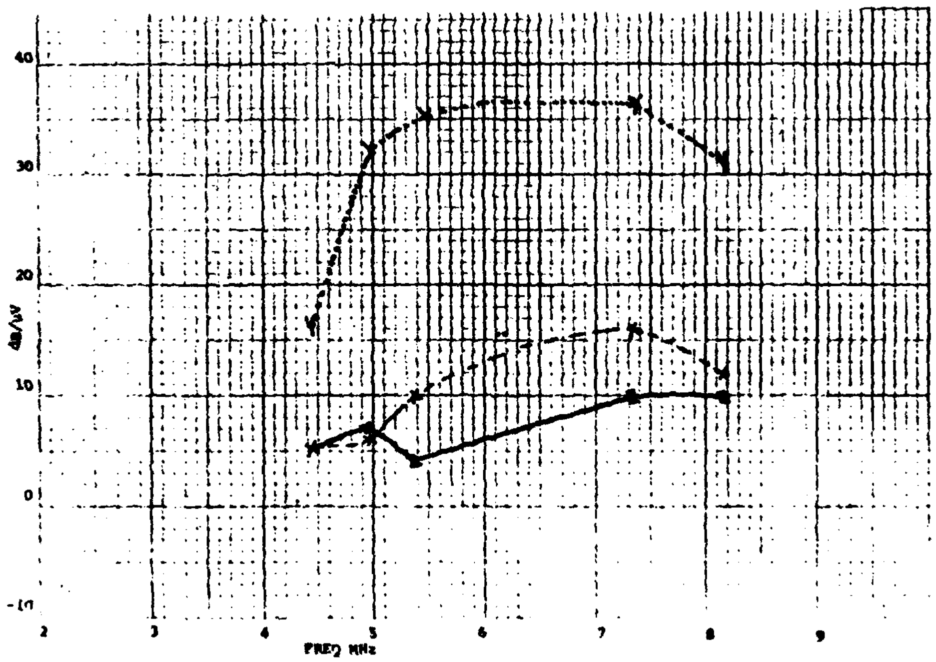


Figure 29. Relative characteristic - Wayside to flight line LAS - 8 Aug 81 - 1330 - 1500 hrs - mobile to helicopter shorted loop XMIT

(12) A final ground-to-ground check of the aircraft antenna installation was performed on 31 August 1981, again using the Wayside - LAS communication path and a dipole transmitting antenna. These test results are shown in Table 16 and Figure 30.

TABLE 16. RELATIVE CHARACTERISTIC - WAYSIDE TO FLIGHT LINE LAS

FREQUENCY		X		Y		Z	
CH	MHz	db/μv	I	db/μv	I	db/μv	I
4	3.195	-10	1	26	5	6	2
5	4.445	9	4	44	5	13	4
6	4.927	18	4-5	38	5	10	3
7	5.397	20	5	40	5	10	3
8	7.360	28	5	45	5	30	

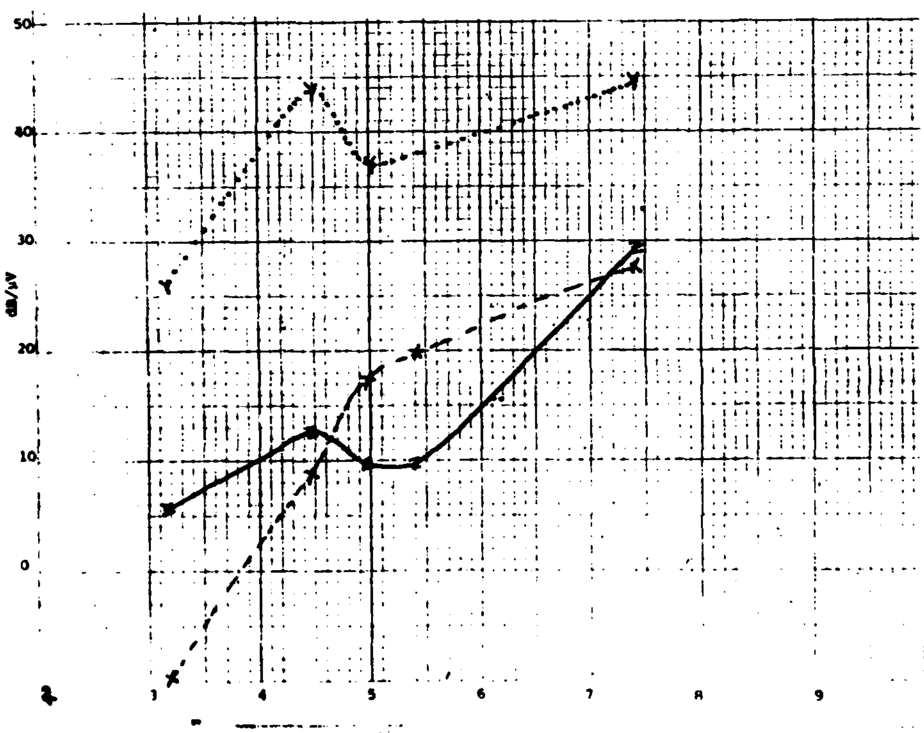
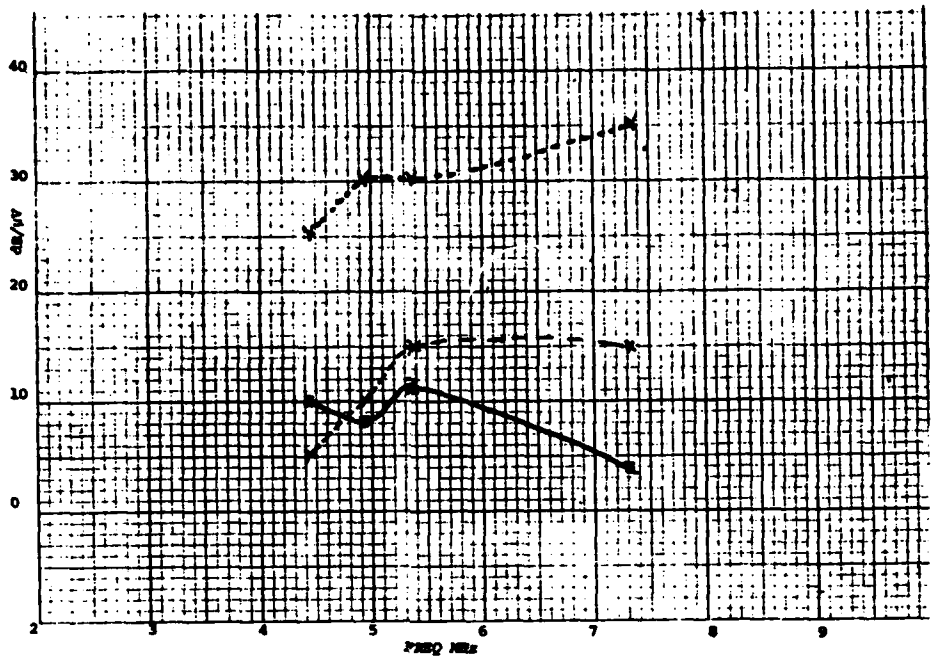


Figure 30. Relative characteristic - Wayside to flight line LAS - 31 Aug 81

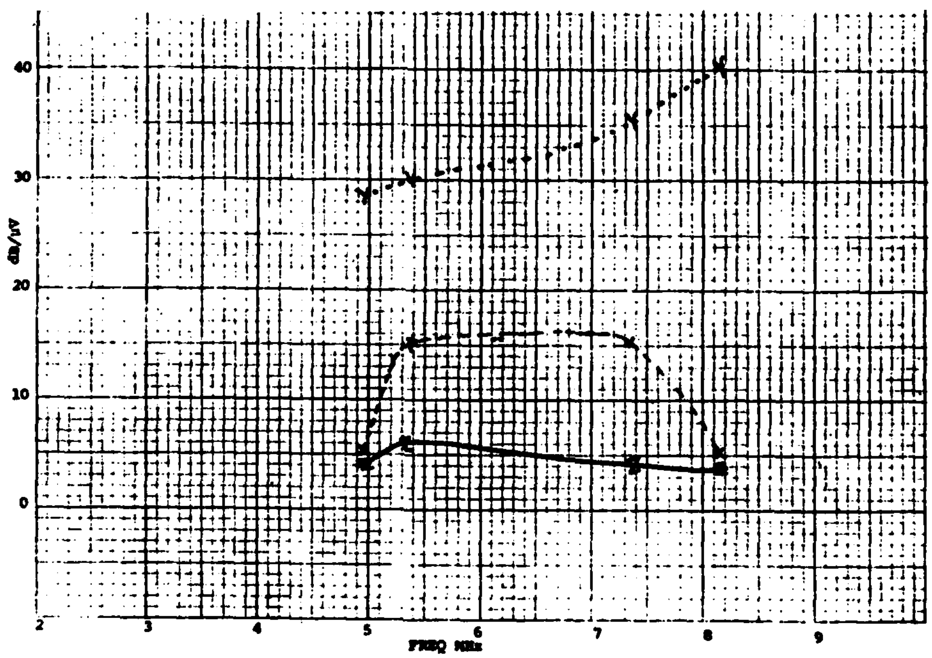
(13) The major flight test was accomplished on 2 September 1981. This consisted of flying from the Fort Monmouth Charles Wood Area to the vicinity of the Delaware Water Gap, PA, a distance of 73 miles. This site provided an opportunity to perform a complete terrain masked communication path test when the helicopter was flown about 100 feet above the Delaware river in between sharp ascent hills that extended to a height of 1000 feet above the water level. Several passes were made through this near ideal nap-of-the-earth (NOE) test site while field strength data was being measured and recorded (Table 17A). A refueling and lunch-stop was made at Wilkes-Barre, PA; then a second low level (NOE) flight was performed on the lee side of the Camelback mountain which rises to a peak height of 2133 feet above sea level approximately 1500 feet above the flight pass. Again comparative data from the three antennas was measured and recorded, see Table 17B. The relative airborne NVIS characteristics are shown in Figure 31A and B.

TABLE 17. NOE FLIGHT TEST (NVIS)

FREQ		X		Y		Z	
CH	MHz	dB/μv	I	db/μu	I	db/μv	I
			A - DELAWARE WATER GAP				
5	4.445	5	2-3	25	4-5	10	2
6	4.927	10	3	30	5	8	2
7	5.397	15	3-4	30	4-5	12	3
8	7.360	15	3-4	35	5	4	1
			B - CAMELBACK MOUNTAIN				
6	4.927	5	2-3	28	5	4	1
7	5.397	15	3-4	30	5	6	1-2
8	7.360	15	3-4	35	5	4	1
9	8.160	5	2-3	40	5	4	1



A - Delaware Water Gap - 73 miles



B - Camelback Mountain - 86 miles

Figure 31. Relative characteristic - airborne NVIS

b. Discussion.

(1) The Bayshore UPS-192A blade antenna was installed on the bottom of the cockpit section due to convenience of using an available inspection port cover. This position is not the best choice for reception of the NVIS signal mode.

(2) The near-field relative sensitivity data as shown in Table 10A and Figure 24 indicates that the Bayshore active blade antenna, Z, has a notable advantage over the "X" antenna. The variation of sensitivity of all three antennas versus frequency is attributed to the mismatch of the transmitting whip which the signal generator was fed into. Otherwise, the outputs would approximate a straight line.

(3) The first of a series of NVIS mode characteristics of Table 10B and Figure 25 is limited in scope of frequency spread but it is clear that the active "Y" antenna can provide a notable advantage over "X" and "Z."

(4) The second NVIS mode characteristic was performed using only the X and Y antennas. The ground-to-ground data of Table 11 and Figure 26A show that the performance of the two are about equal. However, during the flight test to Coyle VOR, a distance of 36 miles and to Atlantic City (AC), a distance of 65 miles, the sensitivity of the Z antenna was approximately 10 dB less than the X antenna. It is notable that the intelligibility and field strength while on the ground at Coyle and Atlantic City are about the same and not too much less than the measurements on the flight line at Lakehurst, a distance of 21 miles.

(5) The near field relative sensitivity was rechecked after the installation of a second change-over relay and the results as recorded in Table 10A was confirmed per data shown in Table 13 and Figure 27.

(6) The performance data shown in Table 14 and Figure 28 illustrate about three quarters of an expected NVIS characteristic. The plot is lacking a typical reduction of systems performance that would have occurred, had the frequency been raised two to four megahertz higher. It is evident that an output signal from the Y antenna is a considerable improvement over the X and Z antennas. The lesser performance of the Z antenna, in the NVIS mode, as compared to the near field is attributed to a vertical incidence in the first to a horizontal incidence of the latter.

(7) The characteristic of the near NVIS mode shown in Table 15 and Figure 29 has some differences to that of the Figure 28, attributed to the fact that a mobile shorted loop was used instead of the resonant dipole as the transmitting source and to a change of ionospheric reflective conditions, i.e., data for Figure 28 was obtained in the morning period and the data for Figure 29 was obtained in the afternoon. It is noteworthy to consider the improvement of intelligibility as recorded in Table 15 at each boundry of the NVIS "window."

(8) The final checkout of the antenna systems as performed on 31 August 1981 prior to an extensive flight test on 2 September 1981. This data as recorded in Table 16 and Figure 30 shows that all systems are in a "GO" status.

(9) The results obtained in a morning and in an afternoon flight in a typical NOE environment, as recorded in Table 17A and B and Figure 31A and B provides some clear evidence that the use of the active antenna approach can be an asset in providing a broader "window" from which to choose operational frequencies when operating in the NVIS mode. For example, the intelligibility reading at an operational frequency of 4.445 MHz was raised from a "2-3" for the X antenna to a "4" for the Y antenna, while flying very low in a gap between two mountains. In like manner, the intelligibility was improved at the upper frequency boundary of 8.160 MHz for a "3" for the X antenna to a "5" for the Y antenna. This phase of the evaluation is considered to be the most significant of all tests performed throughout the project.

7. SUMMARY

a. Objective. To demonstrate improved signal-to-noise ratio in a High Frequency Single Sideboard (HF SSB) system by use of a dedicated antenna receive function in addition to a transmit function.

b. Approach. An active antenna concept was chosen as the primary approach to achieving the objective. Two types of active antennas were considered, a voltage probe and a current probe. The voltage probe type was a commercial version, manufactured by Bayshore Systems Corporation and the current probe type was completely developed in-house. The current probe was simply an "add-on" ancillary device to the shorted-loop antenna.

The lab-built active device provides electronic tuning of the shorted-loop, a stage of RF gain and an impedance matching stage. The components to provide these functions were housed in a small 2 by 2 by 4-inch mini-box and physically installed at the feed point or "gap" of the shorted loop antenna.

c. Ground-to-Ground Tests. The initial tests of the Bayshore, lab-built and the passive (original shorted-loop design) antennas were performed on a mock-up or empty shell of a UH-1 helicopter, while positioned on a 30-foot high turntable tower. The lab-built active antennas showed a differential of 30 to 40-dB advantage in field strength over the passive antennas and the Bayshore device was found to be comparable to the passive antenna. The signal-to-noise improvement ratio of the lab-built device was found to be in the range of 5 to 10 dB above the passive antenna across the low portion of the HF band.

d. Ground-to-Aircraft Tests. The active lab-built device was integrated with a normal AN/ARC-174 HF SSB radio set, where a special installation was made on a flyable UH-1H helicopter, using the shorted-loop antenna. The Bayshore device was mounted on the underside of the cockpit area. Several ground-to-aircraft tests were made while the aircraft was on the ground, but positioned in a way that the NVIS mode was being used. Two successful flight tests were accomplished, one where only the passive and the Bayshore devices were used and evaluated at ranges of 36 to 65 miles. The second and major flight consisted of several-low level passes about 100 feet above the Delaware river at a geographical point known as the Delaware Water Gap; distance of 73 miles from the ground station. This location provided a typical, complete non-line-of-sight condition as a result of terrain masking, that is considered to be common to a NOE flight regime. The active lab-built antenna system provided a worth while signal strength improvement and signal/noise ratio over the passive antenna during all phases of the flight. The most significant improvement was at the lower and upper boundries of the NVIS frequency "window"; thus, in fact, providing a wider window from which to choose workable frequencies.

The Bayshore UPS-192A voltage-probe active antenna proved to be equal in performance to the shorted-loop antenna. No increase in signal strength was found and the output contains some noise energy that originates within the antenna system itself, noticable at low intensity signal levels. The Bayshore device could be recommended where surveillance alone is required and the use of a 12 to 16-foot aluminum tube that is necessary for the shorted-loop is not justified.

8. CONCLUSIONS

a. The active antenna provides a sensitivity improvement ranging from 25 to 30 dB over the currently used passive antenna.

b. The active antenna provides a signal-to-noise ratio improvement of 5 to 10 dB through the lower portion of the HF band (2-10 MHz). This feature can be used to increase the width of the frequency "window" when using the NVIS mode.

c. The use of varicaps in tuning the shorted-loop can provide very rapid scanning over a broad range of frequencies within the lower portion of the HF band. The present shorted-loop design is passively tuned by cumbersome mechanically driven capacitors, thus preventing a rapid receive scan mode.

d. The Bayshore UPS-192A antenna is not considered to have characteristics that would contribute to improved sensitivity or signal-to-noise ratio in the low end of the HF band, when compared to the passive 12 to 16-foot shorted-loop antenna.

e. The ILIR objectives have been achieved and the idea is relevant to a possible improvement of the HF SSB system that is to be implemented as a part of the NOE Communication System.

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APPENDIX. BAYSHORE UPS-192A

1. GENERAL DESCRIPTION

The UPS-192A Active Antenna System is designed for the reception of signals in the frequency range from 2 MHz to 30 MHz. Three isolated outputs are provided.

The system consists of a blade assembly and distribution amplifier. The antenna blade assembly contains the antenna rod and matching amplifier. Interconnection of the blade assembly and distribution amplifier is by means of RG-22B/U balanced coaxial cable. Signals from the matching amplifier and power to the matching amplifier are both carried by the interconnecting cable. The interconnecting cable is driven from a balanced source and terminated by a balanced load equal to the characteristic impedance of the cable to maintain a VSWR over the operating frequency range of the antenna. The use of the balanced transmission line minimizes extraneous signal pick-up in the interconnecting cable. The Blade Assembly is specially coated to minimize effects of ionization and precipitation static.

The three signal outputs are available at BNC coaxial connectors on the Distribution Amplifier unit. The antenna system operates from +28 volts DC applied via the input power connector on the Distribution Amplifier unit. The antenna system is placed in operation by the application of input power.

2. TECHNICAL SPECIFICATIONS (Preliminary)

Signal Outputs --------------------------	Three outputs each covering the frequency range from 2-30 MHz.
Effective Height[1] ----------------------	25 centimeters nominal
Dynamic Range ---------------------------	Will accomodate signal levels from noise threshold up to 4 volts/meters
Load Impedance (all outputs) ------------	50 ohms unbalanced. Will operate into other load impedances
Output Impedance (all outputs) -----------	Output source impedance is 50 ohms unbalanced
Size (inches)	
Antenna Blade Assembly -----------------	Approximately 5 by 2 by 9-1/8 high
Distribution Amplifier -----------------	4-3/4 by 5-1/4 by 4 inches overall
Power Requirements ----------------------	+22 to +32 VDC 140 ma nominal at 28 VDC

[1]Open circuit output voltage from antenna system 50-ohm source impedance is equal to the voltage induced in an antenna of 25 centimeter effective height.

FILM

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