Hf communication program finds antenna's best fire angle

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Determining the feasibility of high-frequency radio communication between any two points goes a lot faster with the HP-25 program described here. The HP-25 performs a rapid series of calculations on a single equation relating transmission distance and the height of the reflecting layers in the ionosphere to an antenna's vertical (firing) angle of radiation and the number of skips (hops). The program will determine the firing angle to which the antenna must be tilted to obtain the highest field strength at the receiving end. If the antenna cannot be steered in the vertical plane, the program can be used to ascertain whether the number of hops is excessive for a given distance, layer height, and firing angle.

Despite the simplicity of the equation on which the program is based, the fact that the density and height of the layers are subject to diurnal, seasonal, and annual variations, plus the fact that the calculation does not take into account the exact frequency of operation, reasonably accurate results are obtained in the 3-to-30-megahertz portion of the spectrum.

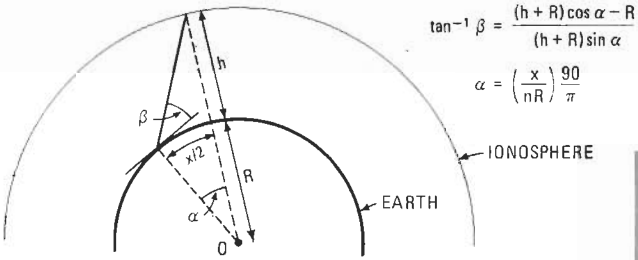
The program solves the equation:

$$\tan^{-1}\beta = \frac{(h+R)\cos\alpha - R}{(h+R)\sin\alpha}$$

where:

$$\alpha = \frac{x}{nR}\,\frac{90}{\pi}$$

β = the firing angle
h = the height of the D, E, F_1, or F_2 reflecting layer
R = the radius of the earth
α = the angle measured from the center of the earth



LAYER	h (km)
D	60 – 90
E	100 – 115
F_1	160 – 210
F_2	210 – 400

(a)

FIRE ANGLE: LISBON-BERNE (x = 1600 km)

n	h – LAYER HEIGHT (km)			
	110	175	250	400
1	4°09′12″	8°33′42″	13°25′07″	22°14′01″
2	13°26′46″	21°32′13″	29°41′55″	42°18′18″
3	21°02′25″	31°42′49″	41°23′35″	54°17′01″
4	27°42′05″	39°53′47″	49°53′37″	61°49′04″

(b)

Ionospheric propagation. Antenna's firing-angle equation is derived from simple geometric considerations and yields fairly accurate results (a). Vertical angle of radiation required is tabulated versus layer height and hop number for the path separating Lisbon and Berne (b).

corresponding to the distance of a half hop

x = the distance between stations

n = the integral number of radio-signal hops.

This equation is based on the assumptions that the earth and ionospheric-layer surfaces are concentric, and that the angle of incidence is equal to the angle of reflection for radio waves striking the layer boundaries.

The equation is derived from the geometrical considerations shown in Fig. 1a. Given x, n, and several values of h, the program will determine the firing angle for each h and for integer values of n.

A simple example underscores the value of the program. In this case, the firing angles are sought for the path from Lisbon in Portugal to Berne in Switzerland, a distance of 1,600 kilometers. After the program has been keyed in, the x and h values and system constants are entered in registers R_0 through R_7 respectively. Then pressing 0, R/S initiates the calculation for β. If the user wants to tabulate the data, O, R/S should be pressed immediately after the first β has been found, to permit the calculator to advance to the second h for n = 1. If just R/S is pressed, n will be incremented by 1, and β will be found for n = 2 at the first specified h; it will not be possible to then find β at n = 1 at h_2 unless the program is reinitialized. The tabulated data is in Fig. 1b.

Unlike a general calculator program, this program requires that the user have a working knowledge of hf propagation in order to interpret the information generated—a blind reliance on the data produced is not possible. A knowledge of the relation of layer height and density to critical frequency, maximum usable frequency, etc., is necessary if one is to realize, for example, that it is not likely that a signal at 3 MHz can be made to traverse a distance of 1,600 km at h = 400, n = 4, and $\beta = 61°$, at high noon on any given day. □

HP-25 IONOSPHERIC PROPAGATION PROGRAM

LINE	CODE	KEY
01	14 11 00	f FIX 0
02	15 71	g x = 0
03	13 11	GTO 11
04	24 05	RCL 5
05	23 61 00	STO X 0
06	01	1
07	51	+
08	23 05	STO 5
09	23 71 00	STO ÷ 0
10	13 22	GTO 22
11	24 01	RCL 1
12	24 02	RCL 2
13	24 03	RCL 3
14	24 04	RCL 4
15	23 03	STO 3
16	22	R↓
17	23 02	STO 2
18	22	R↓
19	23 01	STO 1
20	22	R↓
21	23 04	STO 4
22	24 05	RCL 5
23	14 74	f pause
24	24 04	RCL 4
25	14 74	f pause
26	24 00	RCL 0
27	24 06	RCL 6
28	71	÷
29	24 07	RCL 7
30	61	X
31	14 04	f sin
32	14 73	f Last x
33	14 05	f cos
34	24 04	RCL 4
35	24 06	RCL 6
36	51	+
37	61	X
38	24 06	RCL 6
39	41	−
40	21	x⇄y
41	71	÷
42	24 04	RCL 4
43	24 06	RCL 6
44	51	+
45	71	÷
46	15 06	g tan⁻¹
47	14 00	f→ HMS
48	14 11 04	f fix 4
49	13 00	GTO 00

REGISTERS	
R_0	x
R_1	h_1
R_2	h_2
R_3	h_3
R_4	h_4
R_5	$n_0 = 1$
R_6	R = 6367 km
R_7	$90/\pi$

INSTRUCTIONS

- Key in program
- Enter RUN mode
- Key in transmitting distance
  (x), STO 0
- Input heights of D, E, F_1 and/or F_2 layers
  (h_1), STO 1, (h_2), STO 2, (h_3), STO 3, (h_4), STO 4
- Store initial hop number, earth radius and equation constant
  (1), STO 5, (6367), STO 6, (90/π), STO 7
- Press 0, R/S
  Skip number, h_1, and fire angle is displayed.
- Press 0, R/S, to investigate the layers in sequence for a given skip number, or press R/S to increase the skip number for a given layer height.