CHAPTER VIII

IONOSPHERIC LAYERS AND FREQUENCY SELECTION

8-1. Introduction

Energy radiated in directions above the horizon will travel through space until it reaches the ionized region in the upper atmosphere. There, if conditions are favorable, the path of the wave will be bent earthward. Such a sky wave may return to earth at very great distances from the transmitter, and is the means by which long-distance radio communication is achieved.

8-2. Ionospheric Layers

In the day-time, the upper parts of the earth's atmosphere absorb large quantities of radient energy from the sun, so that considerable ionization of its constituent gases occurs. It is a generàl accepted fact that the ionization is distributed in stratified layers. The D layer exists at heights of 30-55 miles above the earth. The F region extends from approximately 100-250 miles above the earth, with two well defined layers existing during the day-time hours. The lower region is called F_1, while the upper region is called F_2 layer. The F_2 layer attains the highest degree of electron density of any of the ionospheric layer.

In night-time, the F_1 layer and F_2 layer coalesce to form a single night-time F_2 layer, at a height of about 200 miles above the earth.

The E layer becomes reduced in electron density and allowed for the passage of sky waves with minimum attenuation. The D-region is also largely absent at night.

Scattered patches or clouds of relatively dense ionization occasionally appear at height approximately the same as that of the E layer for reason not yet known. This Sporadic-E Ionization (E_s) is most prevalent in the equitorial regions, where it is substantially continuous in both day- and night-times.

8-3. Cyclic Variations in the Ionosphere

Since ionization depends upon ultraviolet radiation, conditions in the ionosphere vary with changes in the sun's radiation. In addition to the daily variation, seasonal changes also result in critical frequency variations. Very marked changes in ionization also occur in step with the 11-year sunspot cycle.

Typical ionospheric behavior is illustrated in Fig. 8-1, which shows the monthly median diurnal variation of virtual heights and critical frequencies of the E, F_1, F_2, and E_s layers for the month of January 1964. This data is taken at Bangkok, Thailand, and is typical of what can be expected in the equilateral latitude near the minimum of the 11-year sunspot cycle. It will be noted that the critical frequencies of the regular layers decrease greately during the night as a result of recombination in the absence of solar radiation. However, the E_s critical frequency shows irregular variation throughout the day and night, a fact which suggests that E_s is affected strongly by factors other than the

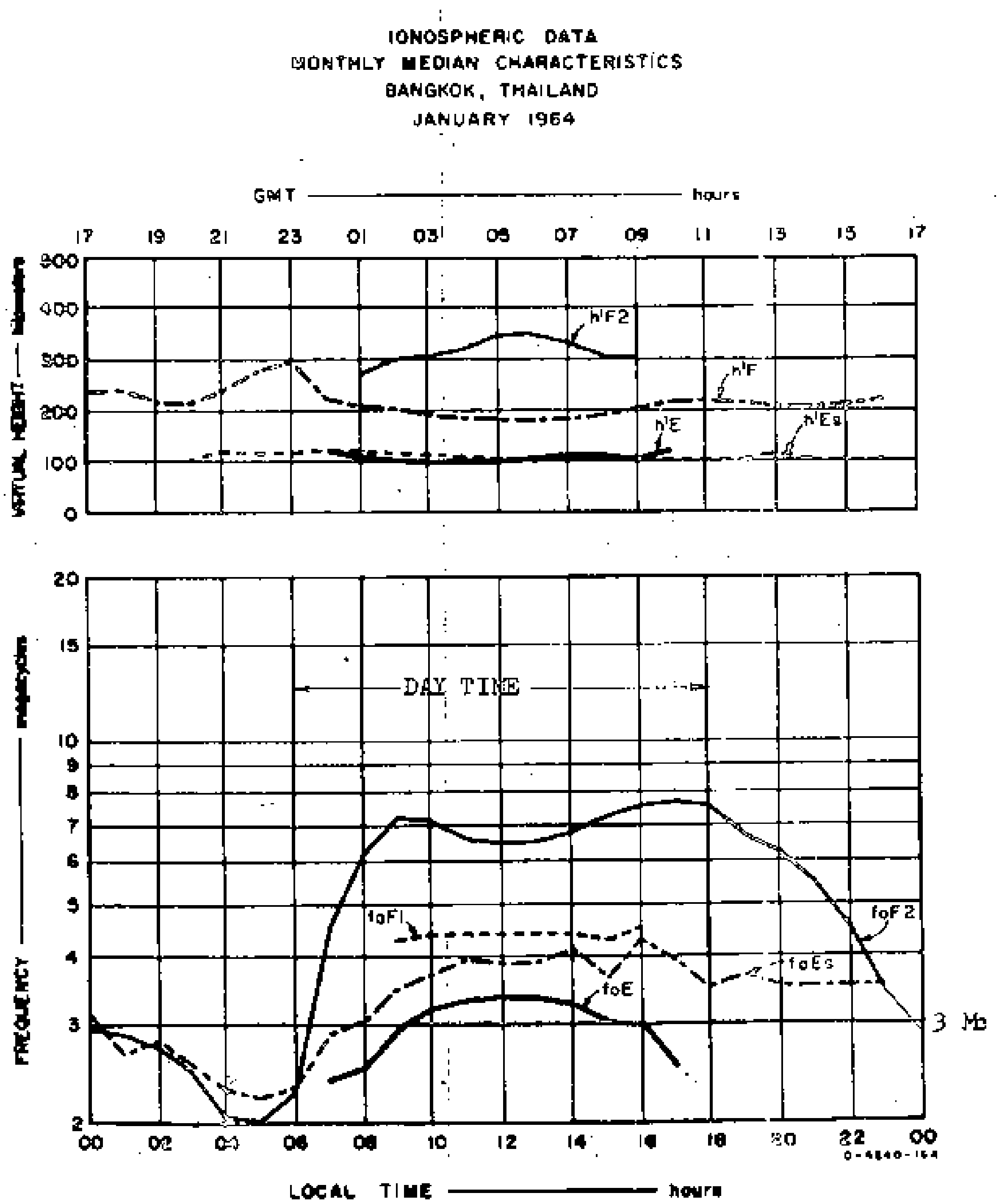
IONOSPHERIC DATA
MONTHLY MEDIAN CHARACTERISTICS
BANGKOK, THAILAND
JANUARY 1964
GMT hours
VIRTUAL HEIGHT — kilometers
h'F2
h'F
h'E
h'Es
FREQUENCY — megacycles
DAY TIME
foF1
foF2
foEs
foE
3 Mc
LOCAL TIME hours

Fig. 8 - 1.

solar variation.

8-4. Long Distance Short Wave Communication by Reflection

All long distance short-wave communications take place by means of ionospheric reflections. For any given set of conditions there is generally a particular range of freqnencies which can be used for such communications. The upper limit is the maximum usuable frequency (MUF), which depends on the distance of transmission and the heights and electron densities at the point or points of reflection in the ionosphere. The lower-frequency limit depends on the ionospheric absorption over the path, the radiated power and the noise level at the receiver, since the losses in the ionosphere increase with wavelength. In general, the frequency which gives the best signal is the maximum usable frequency, In practice, the optimum frequency is taken at 15 percent below the maximum usable frequency to allow for short-time fluctuation in the MUF[38]. The MUF relates to the critical frequency according to the secant law:

$$\text{MUF} = f_c \sec \phi \qquad (8\text{-}1)$$

Since, as shown in the ionospheric chart in Fig. 8-1, the critical frequency tends to be high during the day and low at night. So, the MUF used for 24-hour services should follow the same variations. But communication stations work in fixed bands of frequencies, it is not possible to choose or change the MUF at will. Instead one frequency that gives relatively good result for communication in most of the day-time is chosen and fixed as a day-frequency, and another lower frequency that gives an average good reception for most night-time is chosen and fixed as a night frequency.

In long-distance communication, the optimum frequency is usually determined by the F_2 layer. However, at intermediate distances, such as 200 to 1000 km. and especially in the equitorial regions, the lower height of the E layer causes the angle of incidence of the wave at the layer to be much more glancing than for the F_2 layer, then during the day-time, the E layer nearly always determines the MUF. In night-time, the F_2 layer determines the MUF.[39]

Although the E_s layer exists all the time both day and night, but it's highly unpredictable, so it cannot be relied upon for regular transmission.

The optimum frequency increases with path distance up to the maximum distance for one-hop transmission, which averages 4,000 km. for the F_2 layer and 2,000 km. for the E layer. In point-to-point communication using high frequency waves, it is desirable to employ a directive transmitting antenna. The energy should normally be directed over the great circle path and at a vertical take-off angle corresponding to the fewest number of hops possible between transmitter and receiver. The vertical take-off angle corresponding to a given value of virtual height and a specified one-hop distance can be found from Transmission Chart Fig. 8-2. For intermediate distance 500 km, when considering the reflection at E layer (virtual height = 100 Km), the angle of departure = 21 degrees and the value of $\sec\phi = 2.5$, but when considering the reflection at F_2 layer (virtual height = 300 Km), the angle of departure = 48.5 degrees and $\sec\phi = 1.32$.

TRANSMISSION CURVES SHOWING VERTICAL ANGLES

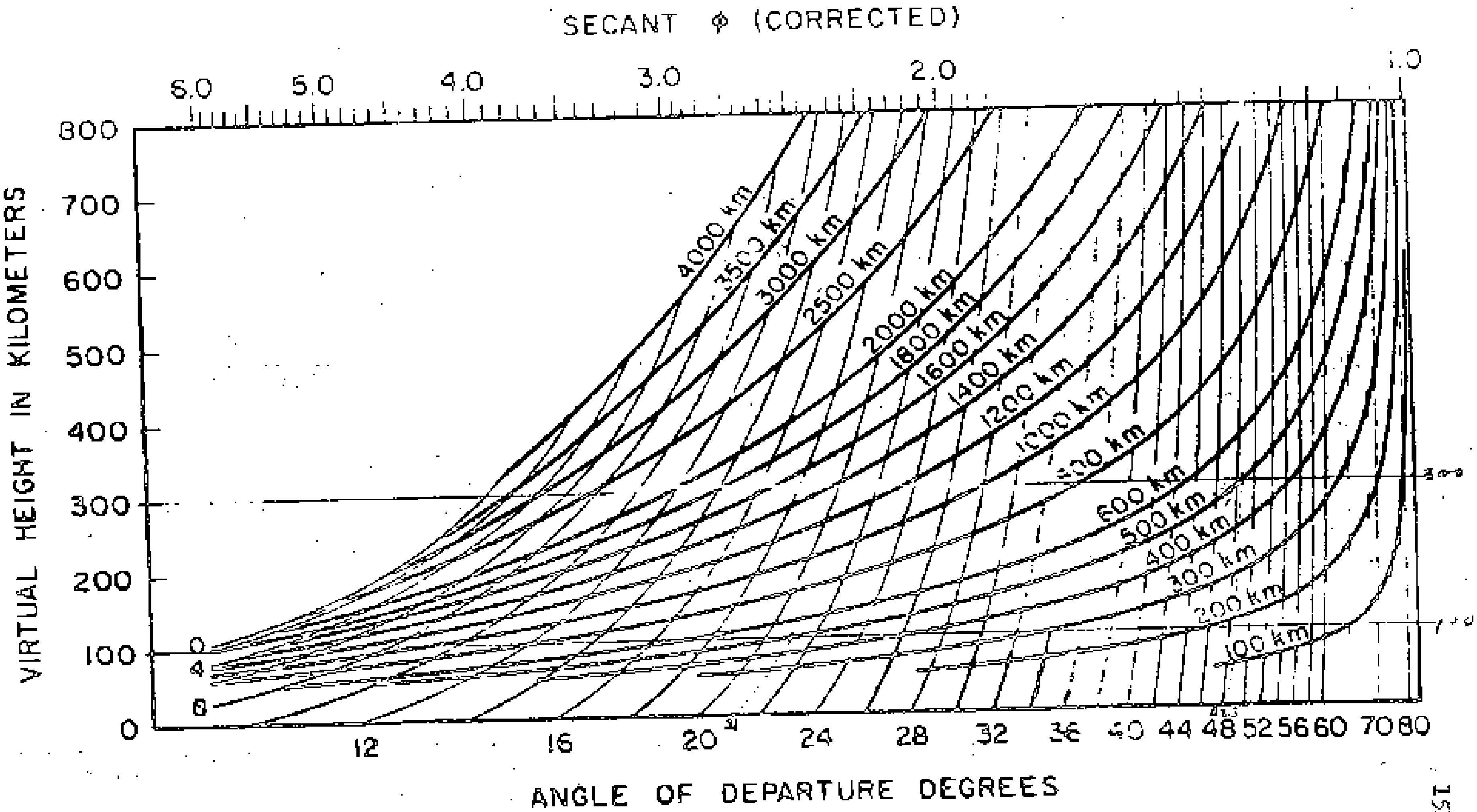

Figure 8-2.

8-5. MUF Predictions

There are several prediction methods in current use. They are designed to meet the particular need of different countries and the needs of different users within a particular country. For the countries located in high latitudes, or for long distance circuits, need an accurate system for the polar and auroral zones by utilizing the prediction chart such as the CRPL-D Series "Basic Radio Propagation Predictions". Some users are only interested in what conditions are likely to be several years in the future and so require less accuracy than others who need predictions, say, three months in advance.

For intermediate range communication in equitorial latitude as in domestic circuit, we need only an average range of frequency which would not fail to propagate for at least 50 percent of the time. Typical values are 5-10 Mc during the day and 3-5 Mc during the night.

The following is the typical way of considering the MUF for 24 hours service by taking the ionospheric chart taken at Bangkok in January 1964 as an example.

In the day-time, with E layer, the critical frequency which covers more than 50 percent of the time is about 3 Mc. In night-time, with F_2 layer, the critical frequency which covers more than 50 percent of the time is 3 Mc.

From the Transmission Curve in Sec. 8-4, sec ϕ for E layer = 2.5 and for F_2 layer = 1.32. So the MUF for day time is given by

$$MUF_{day} = 2.5 \times 3 = 7.5 \text{ Mc}$$

and the MUF for night time is given by

$$MUF_{night} = 1.32 \times 3 = 3.96 \text{ Mc}$$

The above values of MUF are those that fit for January, 1964. For other months or other years, the variations of the MUF should take place according to the behavior of the ionosphere but only slightly. As already stated, we could not change the MUF at will, so we must select the MUF definitely. The circuit between Ubol and Bangkok which is 500 Km apart uses the day frequency at 7.607 Mc and night frequency at 3.370 Mc is an example.