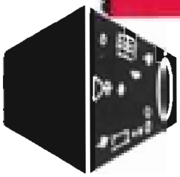
Frequency-Distance Separation Curves



INTRODUCTION

As every communicator is aware, the radio frequency spectrum is a limited resource that must be managed efficiently to assure its availability to all users. Consider the problems facing the tactical frequency manager who must assign operating frequencies for a number of VHF-FM nets employing AN/VRC-12 radios. He must know the answers to several important questions if he is to make effective use of the limited set of frequencies he has at his disposal:

First, how far apart must the closest terminals of two nets be before they can be assigned the same operating frequency without creating a co-channel interference problem?

Second, what minimum frequency separation is required for collocated operation of two radios without mutual degradation of performance occurring due to adjacent channel interference?

Finally, what trade-offs can he make between frequency and distance separations to accommodate all of his requirements for spectrum utilization?

One of the more useful tools that can be used to manage the electromagnetic spectrum, particularly for tactical frequency engineering, is the frequency-distance (F-D) separation curve. The purpose of this discussion is to provide a simplified explanation of how to interpret such curves in their application to spectrum management problems. To provide the reader with a better understanding of the utility of such curves, a brief discussion of the theory behind their development is presented.

DEGRADATION-FREE PERFORMANCE CRITERIA

Due to the existence of radio noise, no spectrum-dependent material operates in an environment that is completely free of performance degradation. Thus, "degradation-free" operation of a given system is usually defined in terms that establish a level of system performance that is acceptable despite the existence of the background radio noise. Acceptable performance may be stated in terms of an allowable bit error rate for a digital data communications system, a tolerable false alarm rate for a radar, or a minimum articulation score (or index) defining an acceptable level of intelligibility for voice communications.

When electromagnetic interference (EMI) is present in addition to the radio noise in the environment, degradation-free operation can be maintained only so long as the defined minimum performance level is maintained. To accomplish this, the level of the minimum desired signal received (S_{min}) must exceed the level of the interference present (I) by some determinate amount defined by a signal-to-interference threshold ratio (S/I_{th}).

$$S - I \geq S/I_{th} \tag{1}$$

where S and I are expressed in dBm, S/I_{th} in dB.

DECOUPLING LOSS FACTORS

When a potential interference situation exists, the total decoupling loss (L_T) encountered by the interfering signal is comprised of two major elements* — the propagation loss (L_p) experienced along the path between the antenna of the interfering transmitter and that of the victim receiver and the frequency dependent rejection (FDR(f)) of the interference by the selectivity characteristics of the victim receiver.

$$L_T = L_p + FDR(\Delta f). \tag{2}$$

Propagation loss in this expression includes any losses that might be encountered due to atmospheric absorption, terrain, and so forth in addition to the basic spreading loss which is a function of path length. The frequency dependent rejection term accounts for the fact that not all of the energy incident on the antenna of the victim receiver is accepted by the receiver.

TOTAL REQUIRED DECOUPLING LOSS

The interference power present in a given victim receiver is a function of the transmitted power level of the source of interference (P_I), the gain of the interferer's transmitting antenna in the direction of the victim receiver (G_{IR}), the gain of the victim's receiving antenna in the direction of the interferer (G_{RI}), and the total decoupling loss encountered by the interfering signal on its path to the detector circuit in the victim receiver (L_T).

$$I = P_I + G_{IR} + G_{RI} - L_T \tag{3}$$

** In certain instances, other factors such as polarization mismatch losses, antenna mismatch losses, and transmission line losses must be considered as well. They are ignored in this discussion only for the sake of simplicity.*

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By substituting Eq. 3 into Eq. 1 and rearranging terms, the criterion for degradation-free performance may be restated as

$$L_T \geq P_I + G_{IR} + G_{RI} - S_{min} + S/I_{th.} \quad (4)$$

This expression implies that degradation-free performance of a given system can be maintained as long as the decoupling losses encountered by any given source of interference exceed the amount defined by the right-hand side of Eq. 4 above, and serves as the basis for the development of frequency-distance separation curves.

THE FREQUENCY-DISTANCE SEPARATION CURVE

In essence, then, a frequency-distance separation curve is simply a plot of the function (defined by Eq. 2) that provides a constant total decoupling loss comprised of varying amounts of propagation loss and frequency dependent rejection. For the sake of convenience, propagation loss is represented on one axis as a function of the distance separation (ΔD) between the victim and interferer; while the frequency dependent rejection is represented on the other axis as a function of the frequency separation (Δf) between the tuned frequencies of the two.

A typical frequency-distance separation curve, such as illustrated in Figure 1, is interpreted as follows:

1. Point A on the curve indicates the minimum separation distance required for co-channel operation of the victim and interferer (i.e., $\Delta f = 0$, and all decoupling is provided by propagation loss).
2. Point B indicates the minimum frequency separation required if the victim and interferer are to be collocated (i.e., $\Delta D = 0$, and all decoupling is provided by frequency dependent rejection).
3. Any other Point C on the curve indicates the frequency separation required between the victim and interferer for a specified separation distance between the two and vice-versa.
4. The F-D curve defines the boundary between the regions of "degradation-free performance" and "degraded performance".

A PRACTICAL EXAMPLE

Let us now return to the problem presented initially: that of the tactical frequency manager who must assign operating frequencies for a number of VHF-FM nets using AN/VRC-12 radios.

The required frequency-distance separation criteria for degradation-free performance of an AN/VRC-12 receiver with a second AN/VRC-12 radio as the interfering transmitter is presented in Figure 2. This curve indicates that net frequency reassignment is possible without degradation for terminal separations in excess of 67 km, while a frequency separation of 1.225 MHz is required for collocated radios. Other points, representing frequency-distance trade-offs, may be read directly from the curve as described above. For example, a terminal separation in excess of 3.5 km is required for a 50-kHz (i.e., one channel) frequency separation, while a 100-kHz (two channel) separation will permit operation of two terminals on different nets to within 700 m of one another.

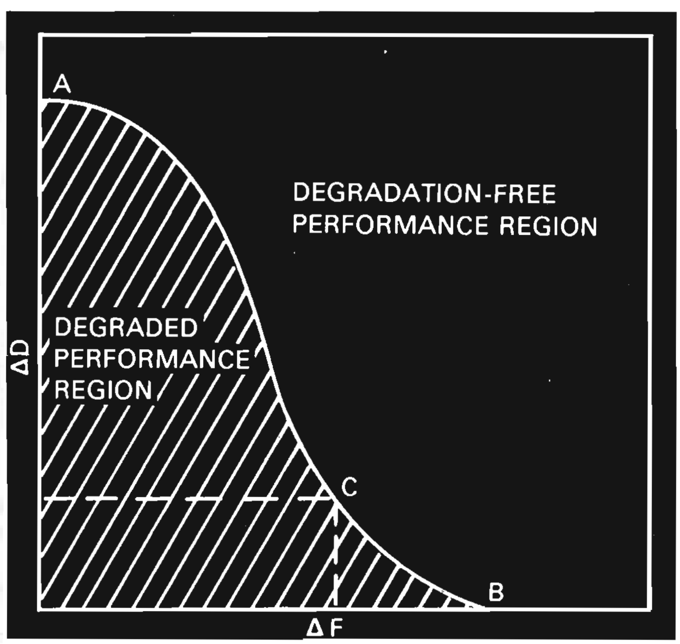

Figure 1. Typical Frequency-Distance Separation Curve.

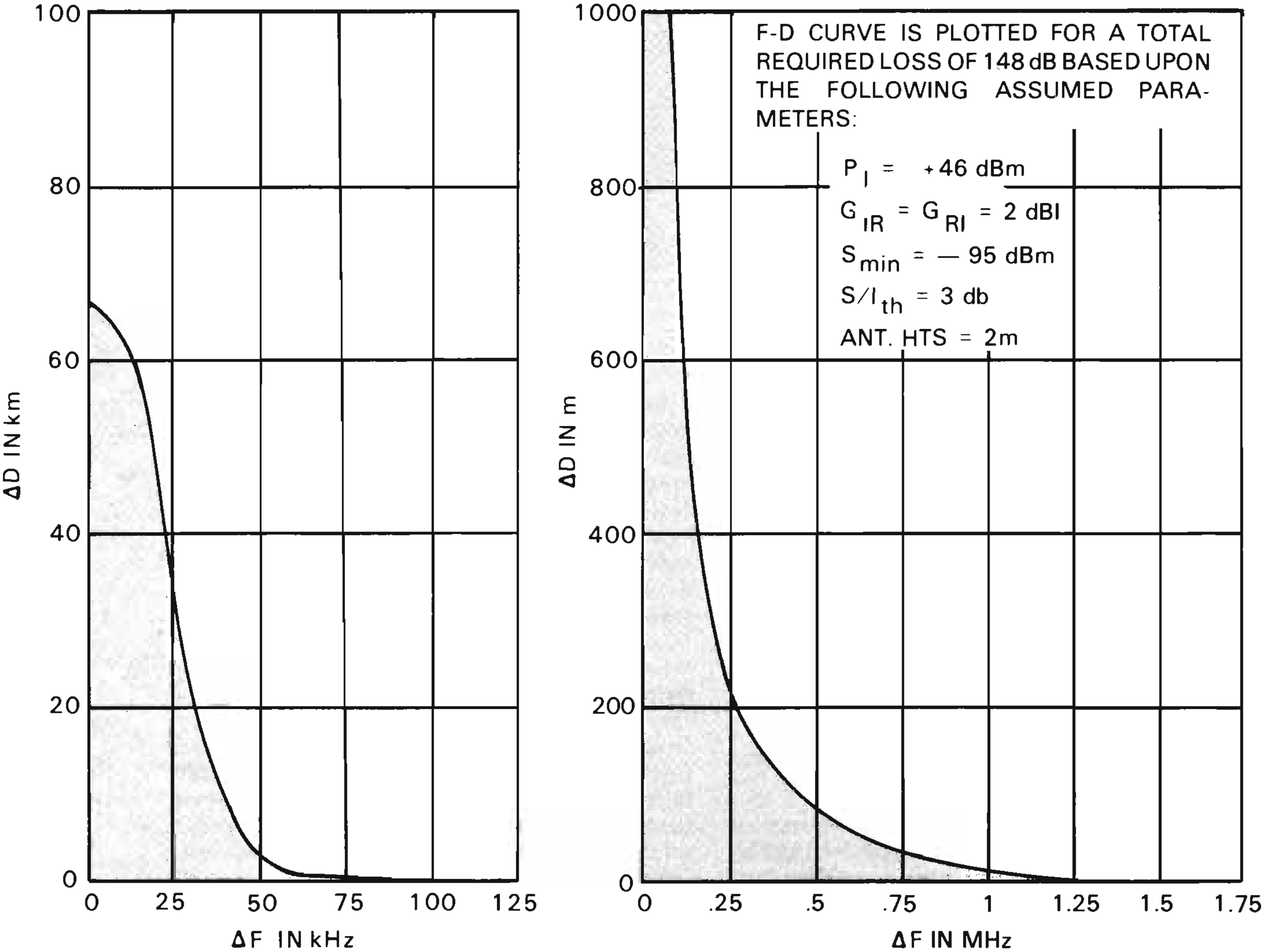

Figure 2. Frequency-distance separation requirements between non-netted AN/VRC-12's.

AVAILABLE CAPABILITIES

The Electromagnetic Compatibility Analysis Center (ECAC) has developed an automated capability for generating F-D separation curves for any victim-interferer pair where the receiver selectivity characteristics and transmitter emission spectrum are defined. A demand capability for generating F-D separation curves is also being planned for the Army Tactical Frequency Engineering System (ATFES).[1] Curves generated by this capability are made available to qualified organizations within the DOD community on a routine basis. Army organizations interested in this service can obtain more information by contacting:

Army Deputy Director (CAA)
DOD ECAC
North Severn
Annapolis, MD 21402
Phone: AUTOVON 281-2103

[1] *Mitchell, E. A. and Faroe, J. J., "The Army Tactical Frequency Engineering System",* THE ARMY COMMUNICATOR, *Summer 1978.*

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