The Calculation of Antennas' Separation for the Optimum Operation of the Space Diversity Reception System of Different Point-to-Point High Frequency Installations in Libya.

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Abstract: The space diversity reception system is the commonest used type of the diversity reception systems. It is used as a receiving terminal to overcome the fading phenomenon depending upon its receiving antennas separation amounts, in various point-to-point High Frequency (HF) installations, which are using operating HFs ranging from 2 To 30 Megahertz (MHz). The aim of this research is to experimentally calculate the antennas separation as times of the transmitting HF signal wave length (λ), and its equivalent in kilometer (km) for the used optimum operation of the space diversity reception system in Libya. Methodology: The λ measurements are calculated as a function of each different path lengths (0,500,1000, and 1500 Km), and its λ of arbitrary operating HF, and for its equivalent amounts in Km are computed as a function of each mentioned different specific path lengths, and its λ of operating HF that is equal the average values (mean is figured for two median values) that are ascertained for two point-to-point path FOT bonds which are calculated practically in Libya, one of them for the winter (December, January, and February), and another one for the summer (June, July, And August) seasons, by using the Central Radio Propagation Laboratory (CRPL) method of ionospheric prediction of the National Bureau of Standards (NBS) in U.S.A. The results show that the antennas separation amounts are obtained as times of λ which are ranging from 17λto 159 λ, and its equivalent, the more applicable results, in Km which are ranging from 0.4 to 15.4 Km. The conclusion: the results in Km can be implemented practically as one of the most important factors of the space diversity reception system good design, which is related for the overall reception performance improvement of the different point-to-point HF installations in Libya.

Keywords: Antennas separation factor, Space diversity reception system, Fading, point-to-point path FOT band in Libya.

I. INTRODUCTION

The diversity reception systems are used widely as receiving terminals of the point-to-point high frequency (HF) installations that are using operating HFs ranging from 2 to 30 Megahertz (MHz), as one measure to overcome the fading problem which has a decisive influence on the performance of HF radio communication systems, whereas this fading issue may be difficult to overcome with increasing power [1].

The most commonly used methods of the diversity are; the frequency and the space diversity to minimize the effects of multipath fading [1], [2].

Since the space diversity reception system is relatively less expensive to implement, and it has some operational and maintenance advantages over the frequency diversity reception system [1], this research will be devoted to the space diversity reception system, specifically to its antennas' separation that is required for the optimum operation.

The purpose of this research is to obtain the antennas separation measurements for the optimum operation of the space diversity reception systems at different specific path lengths, as times of the transmitting HF signal wave length (λ), and its equivalent in kilometer (km). Both of which will be calculated by using the average values (mean of two median values). These average values will be calculated by using the point-to-point optimum working frequency bands that are computed in Libya [3].

A. HF Waves Propagation

The HF waves are characterized by the ground wave and the sky wave. The ground wave follows the surface of the earth and can provide useful communication overland from 16km (10 mile = [mi]) to 160km (100 mi) or more. Whereas, the sky wave is propagated in oblique transmission to word the ionosphere which reflects it back to earth and so on, in the form of one- hop or multi-hops, to cover the long point-to-point links from about 160 km (100 mi) to over 12,800 km (8000 mi) [1].

B. Fading

Fading is defined as the fluctuation in the signal strength at a receiver. It may be rapid or slow, general or frequency selective, but in each case, it is due to interference between two waves, which left the same source but arrived at the destination through different paths. One of the more successful means of combating fading phenomenon is to use the space or the frequency diversity [2].

C. Diversity Reception

Various types of the diversity reception are used widely on the point-to-point HF systems. The diversity reception is based on the fact that the radio signals arriving at a reception point over separate paths may have non-correlated signal levels. More simply, at one instant of time, a signal on one path may be in a condition of fading while the identical signal on another path may not.

The most common forms of the diversity in the radio link systems are those of frequency and space [1], [2].

1. Frequency Diversity

The frequency diversity system utilizes the phenomenon that the period of fading differs for transmitting HFs separated by 2-5%. Such a system employs two transmitters and two receivers, with each pair tuned to a different HF (usually 2-3% separation since narrow HF band allocations are limited). If the fading period at one frequency extends for a period of time, the same signal on the other frequency will be received at a higher level, with the resultant improvement in propagation reliability.

Besides the expense of the additional equipment, the use of additional HFs without carrying additional traffic (which limits utilization of the narrow HF band frequencies efficiently) is a significant disadvantage to the employment of frequency diversity, especially when the HF assignments are even harder to get in highly developed areas where the demand for the HFs is the highest [2], [4].

2. Space Diversity

One of the main attractions of the space diversity is that no additional frequency assignment is required. In the space diversity reception system, if two or more antennas are spaced many wave lengths that should be larger than 6 wave lengths a part (in the vertical plane), it has been observed that the multipath fading will not occur simultaneously at both antennas [1].Sufficient output is almost always available from one of the antennas to provide a useful signal to the receiver diversity system [2]. It is useful for the digital transmission since it reduces error rate [5].

D. Optimum Working Frequency.

The Optimum Working Frequency is often designated as FOT, for the French equivalent (Frequency Optimum de Travail) [2]. In the point-to-point HF transmission, high reliable communications are provided when the operating HF is selected equal or close to FOT [1], [4].

II. METHODOLOGY

A. Calculating the Antennas Separation

The antennas separation required for the optimum operation of a space diversity reception system is calculated by using the following formula [6].

$$S = \frac{3\,\lambda\,R}{L} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where:

S= Separation (meter [m]),

R= Effective earth radius (m),

λ = Wave length (m),

L= Path length (m).

The formula (1) usage requires the following considerations to be used in the experimental calculations:

- Effective earth radius = $\frac{4}{3}$ (actual earth radius = 6370 km) [7], [8].
- In free space [8], $\lambda = \frac{c}{f} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$

Where:

- c= HF signal traveling velocity in free space = 3×10^8(m/sec.).
- f= Operating HF (Hertz [Hz]), where 1 Megahertz (MHz) =10^6 Hz.
- The different point-to-point paths in Libya are taken mostly over land areas.
- L= 0 (km) is considered as 160 km, because it represents the shortest path length over land areas that at it, the fading is likely to occurs.

Therefore, S can be calculated as a function of L, and λ that can be considered in two forms.

1. Calculating S at considering λ is a function of arbitrary f

In this case, S is calculated as a function of L (0, 500, 1000, and 1500 km), and λ that is considered as a function of arbitrary f.

2. Calculating S at considering λ is a function of f that is equal the average values of the point-to-point path FOT bands

S is calculated in this case by following the same manner of the previous case in section 2.1.1, except that λ is considered as a function of f that is equal the average values (mean of the two median values), that are calculated for the two point-to-point path FOT bands which are calculated practically in Libya to each of the same different mentioned path lengths [3].

B. Calculations of the Point-to-Point Path FOT Bands

The point-to-point path FOT bands are calculated experimentally in Libya to the each different path lengths (0, 500, 1000, and 1500 km), for the winter (December, January, and February) and the summer (June, July, and August) seasons, by using the Central Radio Propagation Laboratory (CRPL) method of ionospheric prediction of the National Bureau of Standards (NBS) in U.S.A [3].

C. Calculating the Average Values of the Point-to-Point Path FOT Bands

The mean value is calculated of the two median values to each different mentioned path lengths in Libya. One of them is calculated for the point-to-point path FOT band of the winter season, and the other one of the summer season.

III. RESULTS AND DISCUSSION

The results are shown in Tables 1 and 2.

Table1: The Point-to-point path FOT bands that are calculated practically for the winter and the summer seasons in Libya, at different specific path lengths.

Path lengths (km)	Season	Path FOT Bands (MHz)
0	Winter	2, 2.3, 3.4, 3.8, 3.8, 3.3, 3, 2.6, 2.6, 2.1.
	Summer	2.6, 2.2, 3.5, 4, 4.3, 4.3, 4, 3.4, 2.3, 2.3, 2.4.
500	Winter	2.4, 2.1, 4.1, 7, 7.8, 7.7, 7, 4.3, 2.9, 3.1, 2.4.
	Summer	2.9, 2.1, 3.7, 6.9, 8.3, 8.9, 8.9, 8.4, 6.9, 3.9, 3, 2.8.
1000	Winter	2.9, 3.6, 2.4, 7.2, 11.5, 12.5, 12.3, 11, 6.8, 6.5, 5.1, 5.2.
	Summer	4.3, 2.6, 6, 11.5, 13.8, 14.4, 14.3, 13.5, 11.3, 6.8, 5.8, 4.6.
1500	Winter	6.5, 4.8, 2.9, 9.6, 15.3, 16.6, 16.2, 14.9, 13.3, 13, 9.9, 8.
	Summer	8.4, 7, 7.4, 14.8, 17.8, 18.9, 18.8, 17.8, 15, 12.7, 11.7, 9.6.

Table2: The antennas separation amounts that are calculated as times of λ, and its equivalent in km for optimum operation of a space diversity reception system for a different point-to-point HF installations at each different specific path lengths in Libya.

Path Length (km)	Antennas Separation	
	Times of λ	≈(km)
0	159 λ	15.4
500	51 λ	03.0
1000	25 λ	01.0
1500	17 λ	00.4

The results show the following:

- The contents of both the point-to-point path FOT bands, one for the winter, and the other for the summer seasons, are different at each different specific path lengths, and they are changing when the path length is changed.
- The antennas separation amount results which are as times of λ ranging from 17 λ to 159 λ, and its equivalent the more practical results in km ranging from 0.4 to 15.4 km, depending upon the specific path length, as well as its average values of the point-to-point path FOT bands for the winter and the summer seasons in Libya for the equivalent more applicable results case only.
- The antennas separation amounts at each different specific path lengths are larger than the minimum amounts that are required for that separation which is equal 6 λ.
- While the path length is increased in the linear form, its antennas separation amount is decreased in the non-linear form, as well as its average values of the point-to-point path FOT bands for the winter and the summer seasons in Libya are increased in non-linear form for the equivalent more applicable results in km case only.

IV. CONCLUSIONS

- As the path length increases, fading becomes a major consideration.
- By using the concept of the average value, the whole FOT contents of the point-to-point path FOT bands are described by a single path FOT that is reduced the antennas separation amount results to only one which is considered more applicable to be implemented to entire FOT band contents for both winter and summer seasons at each specific path lengths.
- The antennas separation amount results especially the more applicable in km can be implemented practically as one of the most important factors of space diversity reception system good design. It is related for the overall reception performance improvement of a different point-to-point HF installation in Libya.
- The overall reception performance improvement can be achieved by utilizing at least two antennas in space diversity reception system.
- The space diversity improvement in Libya will be based on a wide antenna spaced that is ranging in a non-linear form from17 λ to 159 λ, that are equivalent to 0.4 to 15.4 km respectively.

V. PROSPECTIVE RECOMMENDATIONS

From this study, it can be recommended that each of a different point-to-point HF installation in Libya may use each of the following:

- The path FOT of the experimentally calculated point-to-point path FOT bands (which extend from 2 to 18.9 MHz) as the operating HF, to achieve high reliable communications. This path FOT will depend upon; the path length, the season, and the local day time,

- The space diversity reception system as the receiving terminal because of; its economic, some operational, and maintenance advantages, to achieve the overall reception performance improvement.

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