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Estimation of Correlation Constant Between Medium Wave and Short Wave Free-Space Communication Systems

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Abstract: The field strength of medium and short wave communication system was calculated and correlated for different wavelengths from the predicted local transmitter to different receiving points at different local times by using Vvednsky and Kazantsev method. A correlation constant is formulated that satisfies the relationship between the field strength of medium wave and short wave communication system. It was observed that this correlation constant varies with local time and wavelength. The average value of the correlation constant is maximum at night and minimum at noon. The calculated field strength of short wave communication system is almost the same with the results obtained by using correlation constant.

Key words: Estimation of correlation, medium and short wave

INTRODUCTION

Mode of radio wave propagation plays an important role in communication system. The radio waves may be classified in various categories in accordance to the mode of propagation. When the antennas are close to the earth, medium or ground wave propagation is prominent. Propagation by means of surface wave is the primary mode of propagation in the frequency range from a few kilohertz up to several megahertz. The maximum range of surface wave propagation depends not only on the frequency but power as well. In this regime, the transmitter power may range from 10 kW upwards to 1 MW for useful propagation and distances of several hundred kilometers are achieved. Earth's attenuation due to ground wave propagation increases as the frequency increases and hence this mode of propagation is suitable for low and medium frequency. All the broadcast signals received during daytime are due to ground wave propagation[1].

The medium wave communication systems are limited by the curvature of the earth and hence these modes of propagation fail for communicate over large distances. Therefore, propagation for higher frequencies and over long distance of thousand kilometers or more are almost exclusively performed by the short wave or sky wave. Hence the sky waves are of practical importance for very long distance radio communication[2].

We know that the radio waves of frequency 2 MHz to 30 MHz (i.e., H.F. signals or short waves) is reflected from the ionosphere but in the day time the lower frequencies of 2-30 MHz are highly attenuated and hence efficient long distance communication or broadcasting is performed in the frequency range of 10 MHz to 30 MHz. Since in night higher frequencies around 30 MHz is not at all reflected back to earth, so during night some what lower frequency is utilized for long distance of broadcasting. Hence, some stations could be designed to provide ground wave service during the daytime and both ground and sky wave service at night[3]. Thus, we need to have the correlation between medium and short wave communication system.

Calculation procedure: To correlate the relationship between medium and short wave, the following parameters have to consider, i.e., local time, distance, frequency, troposphere parameter such as surface refractivity, soil conductivity, humidity, pressure of troposphere and ionospheric parameter such as critical frequency, virtual height, maximum usable frequency, optimum working frequency and skip distance.

The field strength of medium wave and short wave was calculated from the predicted transmitter to different receiving points with the following parameters-

- Power of the transmitter = 100 kw
- Transmitting antenna gain = 20 db
- Height of the transmitting antenna = 120 meter
- Transmitting frequency = 5.4, 6.6, 7.5, 8.5, 10 and 12 MHz

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- The short wave field strength at a distance r was calculated by the formula[4]

$$E_{rms} = \frac{173\sqrt{P_{1KW}G_1}}{r_{km}} F \text{ mV/m} \quad (1)$$

Where P_1 is the output power of the transmitter, G_1 is the gain of the antenna and F is the attenuation factor.

The medium wave field strength was calculated from the equation as follows[4]-

$$E_{rms} = \frac{2.18\sqrt{P_{1KW}G_1}}{r^2_{km}\lambda} h_{tm} h_{rm} \text{ mV/m} \quad (2)$$

Where h_t and h_r are the heights of transmitting and receiving antennas and λ is the wavelength of the transmitting signal. The parameters h_t and h_r of the Eq.(2) depends on dN/dh[5].

To establish the relationship between field strengths of medium wave and short wave of HF, a constant is formulated named as correlation constant. For this purpose, considering the relationship as follows-

$$E_{r.m.s}(\text{short wave}) \propto E_{r.m.s}(\text{medium wave})$$

or, $$E_{r.m.s}(\text{short wave}) = K\, E_{r.m.s}(\text{medium wave}) \quad (3)$$

Where, K is defined as correlation constant.

Putting the values of $E_{r.m.s}$ for short wave and $E_{r.m.s}$ for medium wave from Eq.(1) and (2) in Eq.(3), then

$$\frac{173\sqrt{P_{1KW}G_1}}{r_{km}} F = K\frac{2.18\sqrt{P_{1KW}G_1}}{r^2_{km}\lambda} h_1 h_2$$

or, $$K = \frac{173F\times r\times\lambda}{2.18h_1h_2} \quad (4)$$

$$K = \frac{79.357F\times r\times\lambda}{h_1h_2}$$

Now, putting the value of K in Eq.(3),then

$$E_{rms}(\text{short wave}) = \frac{79.357F\times r\times\lambda}{h_1h_2} E_{rms}(\text{medium wave}) \quad (5)$$

For fixed antenna heights, K will be simplified from Eq. 4 by putting the value of h_1 and h_2.

In this case h_1=120 m and h_2 = 20 m, then

$$K = \frac{79.357F\times r\times\lambda}{120\times 20}$$

and

$$k = 0.033\times F\times r\times\lambda \quad (6)$$

April 28, 2006After putting the value of K in Eq.(3) we can get-

$$E_{rms}(\text{short wave}) = 0.033\times F\times r\times\lambda\times E_{rms}(\text{medium wave}) \quad (7)$$

The average value of K may be formulated as follows-

$$K_{av} = n\times r + c \quad (8)$$

Where, n = slope of the average correlation constant
c = Constant for taking limited distance range.
r = distance from the transmitter in km

The value of n depends on local time as well as the value of c and distance. For fixed distance and local time, the average value of correlation constant may be calculated for two points as follows, i.e.,,

$$K_{av} = \frac{\Delta K_{av}}{\Delta r}.r + c \quad (9)$$

Here, $$n = \frac{\Delta K_{av}}{\Delta r}$$

RESULTS AND DISCUSSION

The medium wave is much attenuated at HF due to the ground conductivity and tropospheric parameters. The variation of medium wave field strength with distance for different transmitting frequency is shown in Fig. 1. The field strength of medium wave shows that the total field is inversely proportional to the square of the distance. It also inversely proportional to wavelength used and directly proportional to the product of antenna heights. The total field strength can be enhanced by using a shorter wavelength and increasing the aerial height. It is also observed that the field strength is negligibly small for large distances i.e., at 300 km and above from the transmitter. The required field strength in daytime is 63

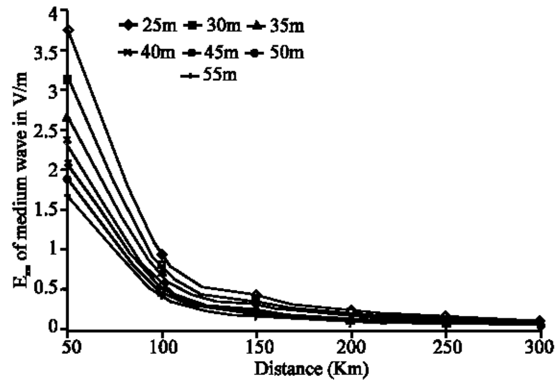

Fig. 1: Variation of HF medium wave field strength with distance for various wavelengths

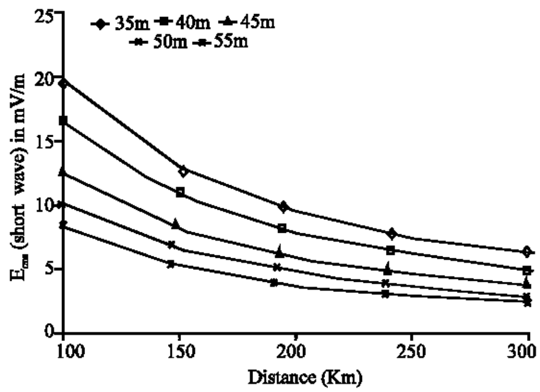

Fig. 2: Variation of short wave field strength with distance for different wave lengths at local time 12 h

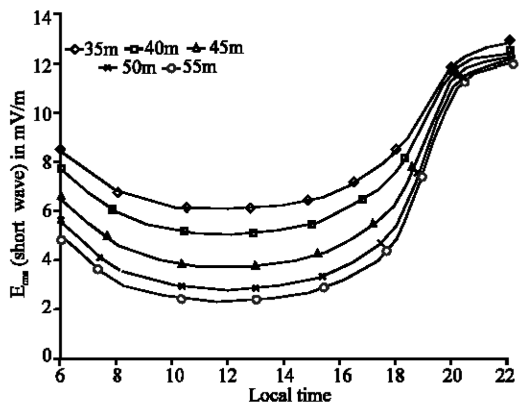

Fig. 3: Variation of short wave field strength with local time for different wave lengths at a distance 300 km from the transmitter

μv/m for reliable reception so the medium wave propagation is not suitable over the long distances.

Variation of short wave field strength with distance for different wavelength and time is shown in Fig. 2 and 3, respectively. It is also observed from Fig. 2 that the short wave field strength decreases with distance i.e., field strength is inversely proportional to the first power of distance, which is obtained from Eq. 1. The local time dependent field strength of short wave shown in Fig. 3. It is observed from the figure that the field is lower at noon on the other hand it is higher after sunset. This is because, the field strength is directly proportional to the attenuation function which varies with solar activity, transmitting frequency, layer parameters and distance from the receiving end.

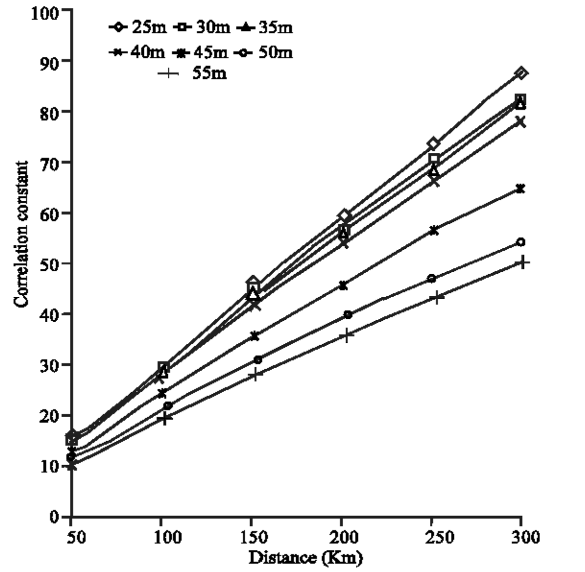

Fig. 4: Distance dependent correlation constant for different wave lengths at local time 12 h

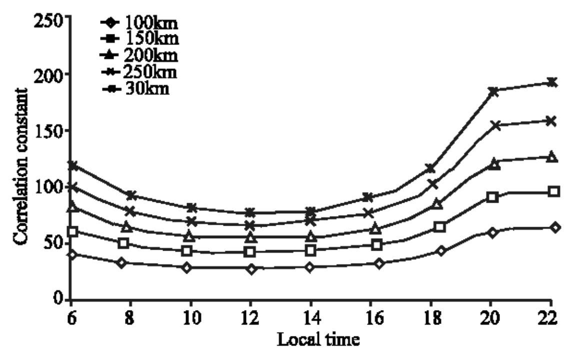

Fig. 5: Variation of time dependent correlation constant for different distances at wave length 40 meter

The variation of the calculated correlation constant with distance and local time with different wavelength are shown in Fig, 4, 5, respectively. The correlation constant increases with distances on the other hand it is minimum at noon and maximum after sunset. Distance dependent

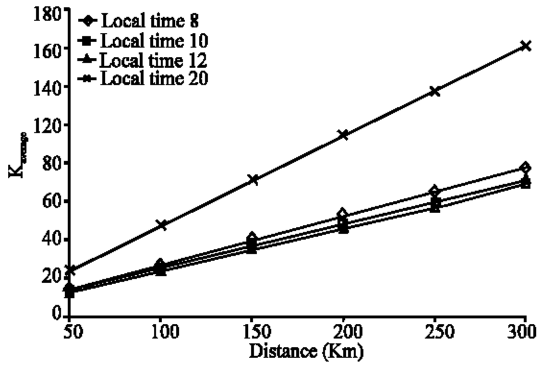

Fig. 6: Variation of kav with distance for differert local time

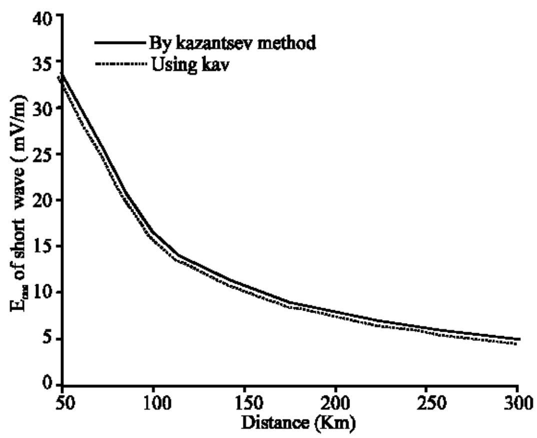

Fig. 7: Correlation between the Erms obtained by Kazantsev and direct method using Kav at local time 12 for 40 meter long wave length.

average correlation constant at different local time is shown in Fig. 6. From the calculated results it is also observed from the figures that the correlation constant is dependent on attenuation function, distance of the receiving point from the transmitter, wavelength of the signal used and also on the antenna heights. The variation of the field strength of short wave with distance that was calculated by Kazantsev method from known medium wave field strength is almost the same with the field strength obtained by using average correlation constant K_{av} (Fig. 7). The percentage of error between these two fields (Fig. 7) lies between 1.3 to 13.7%. The values of correlation constant vary from 10.79 to 256.

CONCLUSION

The correlation constant varies with local time and is minimum at noon and maximum at night. The field strength of short wave obtained by using average value of correlation constant differs slightly from the direct calculated value by using Kazantsev method. From the above prediction, we can easily calculate short wave field strength by using correlation constant when medium wave field strength is known and vice-versa.

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