Modified Huygens' Principle, diffraction and non-rectilinear (spiral) propagation of electromagnetic waves

Diffraction doesn't depend on frequency but on radiation pattern.

Only waves from a perfectly isotropic radiator travel in a straight path!

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Abstract

1. According to Huygens' principle every point on the wave front becomes a source of a *spherical* wave. The sum of these secondary waves determines the form of the wave at any subsequent time. These secondary waves are assumed to travel only in the forward direction. According to the new theory proposed in this paper, however, these secondary waves are *not spherical* waves: their ***radiation pattern is the replica of the radiation pattern of the source of the wave*** . Thus if we put an obstacle between a radiating element and a point in space so that there is no direct propagation from the radiating element to that point, the amount of electromagnetic radiation received through diffraction at that point from the edge of the obstacle depends on the radiation pattern of the source. If the radiating element radiates very small power in the corresponding general direction, less EM waves will be received at that point than if it radiates much power in that corresponding direction.
2. According to our knowledge so far diffraction depends on frequency; lower frequencies are diffracted more than higher frequencies. According to the new theory proposed in this paper, however, ***diffraction directly depends on the radiation pattern*** *of the source and hence of the radiation pattern of each point on the wave front*. If we constructed an antenna for low frequency with the same sharp radiation pattern as an antenna for a very high frequency and tested diffraction, we would prove that *diffraction is independent of frequency*, according to the theory proposed in this paper.
3. According to our knowledge so far electromagnetic waves propagate in straight line in free space. According to the new theory presented in this paper, however, ***only radiation from a perfectly isotropic radiator travels in straight path!*** Therefore electromagnetic radiations from practical radiators such as an antenna are never isotropic, so electromagnetic waves radiated from these always propagates in spiral path around the source, in cosmic scales. Each tiny angular portion of the wave follows a different spiral path which directly depends on the ***gradient of intensity with respect to angle*** at that point, which in turn depends on the angular position in the radiation pattern. Natural sources of light (the sun and the stars) are nearly perfect isotropic

radiators, so light from them should travel in straight path. We consider the sun and the stars as a single source and not the individual radiating atoms inside them.

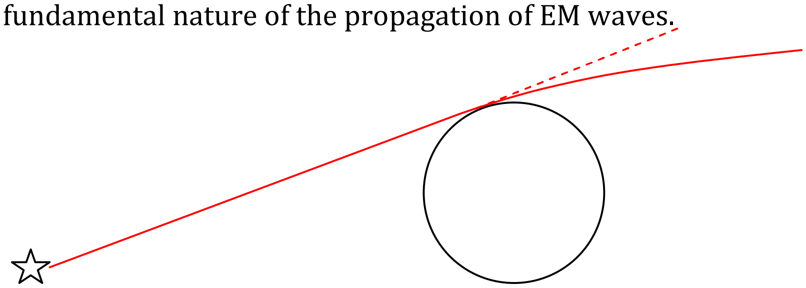
Introduction

According to Huygens' principle every point on the wave front becomes a source of a *spherical* wave. The sum of these secondary waves determines the form of the wave at any subsequent time. And these secondary waves are assumed to travel only in the forward direction. Huygens' principle, together with Fresnel principle, has been applied to study the study and understanding of phenomenon of diffraction. Another established knowledge in physics is that diffraction depends on frequency: lower frequencies are diffracted more than higher frequencies. The other well established knowledge in physics is the rectilinear propagation of electromagnetic waves in free space. However, proposals on the modification of Huygens principle, the spiral propagation of electromagnetic waves and the dependence of diffraction on radiation pattern of the source and its independence on frequency will be presented in this paper.

Discussions

Modified Huygens' principle

The modification made to Huygens' principle in this paper is that each point on the wave front is not a spherical radiator: ***the radiation pattern of each point is the replica of the radiation pattern of the source.*** Electromagnetic waves in general essentially propagate in a spiral path around their source. This spiral path becomes significant only in cosmic scales. Only radiation from perfectly isotropic radiators travels in straight path. The spiral followed by each differential angular portion of the wave directly depends on the ***gradient of the intensity of the wave with respect to angle*** at that point. In a perfectly spherical radiator, this gradient is zero, so the waves in all directions travel in straight lines. Close examination of the phenomenon of diffraction leads us to this fundamental nature of the propagation of EM waves.



In the above figure diffraction of light by an obstacle has been shown. Intuitively, why does the wave bend? We can reason out this phenomenon happens because the space to the right of the light beam has been shadowed by the obstacle. Therefore, the Huygens' points to the right of the beam do not radiate any waves. *The direction of propagation of a wave at any point in space is determined by the contributions of radiating points* *around that point.* Therefore, the wave bends to the right since the points to the right are not radiating.

Spiral path of electromagnetic waves

We can extend this reasoning to the radiation from sources such as an antenna. Therefore the direction of propagation of an EM wave from an antenna at a point in space depends on the radiation patterns of the points around that point. And it follows that the direction of propagation at that point is determined by the gradient with respect to angle of the intensity at that point. *The theory of spiral propagation of electromagnetic waves directly follows from the understanding and interpretation of the fundamental cause of the phenomenon of diffraction:* ***A wave will always spread towards the side with less wave intensity as it propagates forward.*** *This is analogous with gas molecules in a container always spreading to areas where less or no gas molecules exist. Therefore it follows that* ***an electromagnetic wave will not remain confined to the solid angle it was confined to when it left its source, as it propagates forward.***

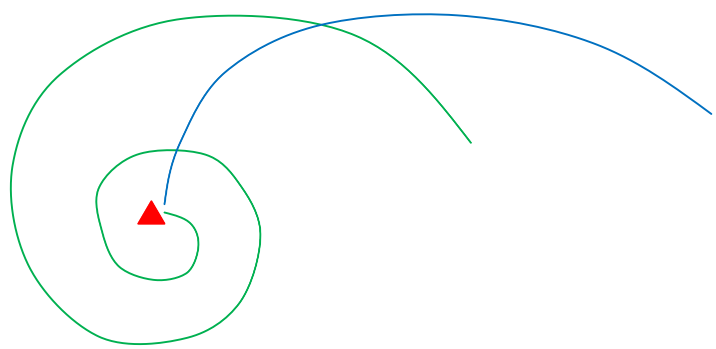


Figure: spiral radiation of electromagnetic wave from a non isotropic radiator.
Green: radiation from a point with high gradient of intensity with respect to angle
Blue: radiation from a point with low gradient of intensity with respect to angle

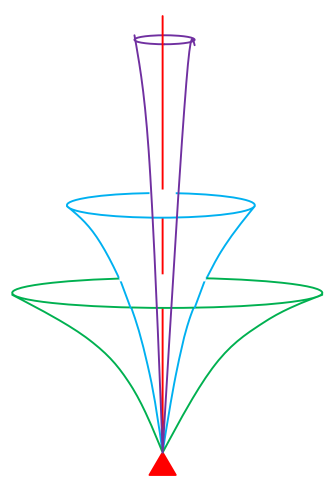
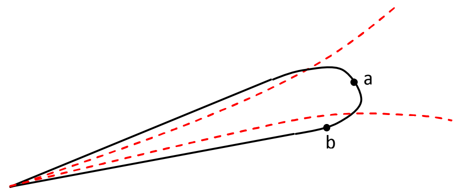


Figure: the waves that follow a spiral path with the same parameters form a ‘spiral cone’, for example.

Therefore, the radiation pattern of an electromagnetic wave radiator (such as an antenna) will be different if measured at different distances. This is because of the non-rectilinear propagation of EM waves. Of course, this theory may not have practical significance because these effects become significant only at great distances.



In the above figure the black line shows the approximate and practical pattern, and the dotted red line shows the exact pattern, with the difference exaggerated. The difference is practically impossible to identify, but becomes significant only on cosmic scales. At point 'a' on the figure the gradient of the wave intensity with respect to angle is minimum or zero, so the wave propagates with minimum or zero amount of curvature (spiral) of its path. At point 'b' the gradient is big, so the wave propagates in more curved (spiraled) path. And each point on the wave front is a replica of the antenna, so each point on the wave front will have the same radiation pattern.

Let us look at a more general case. Imagine two EM wave radiators with the following radiation patterns.

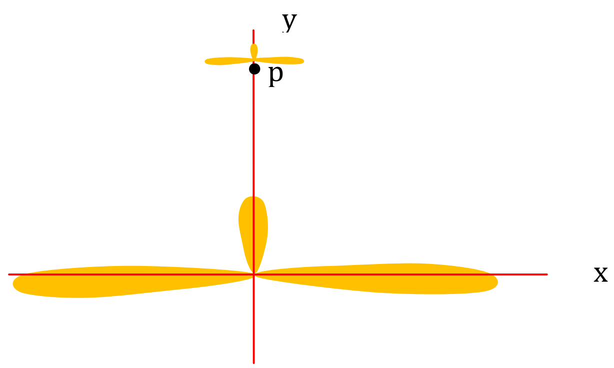


Figure 'a'

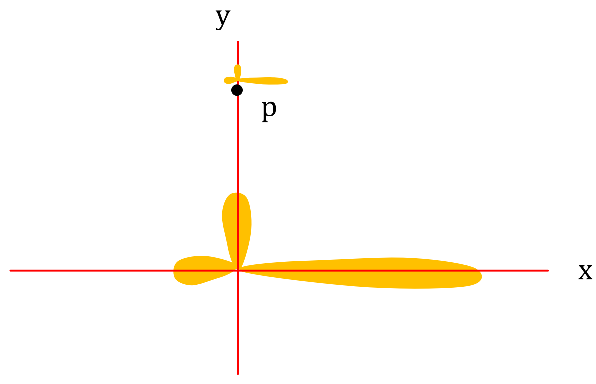
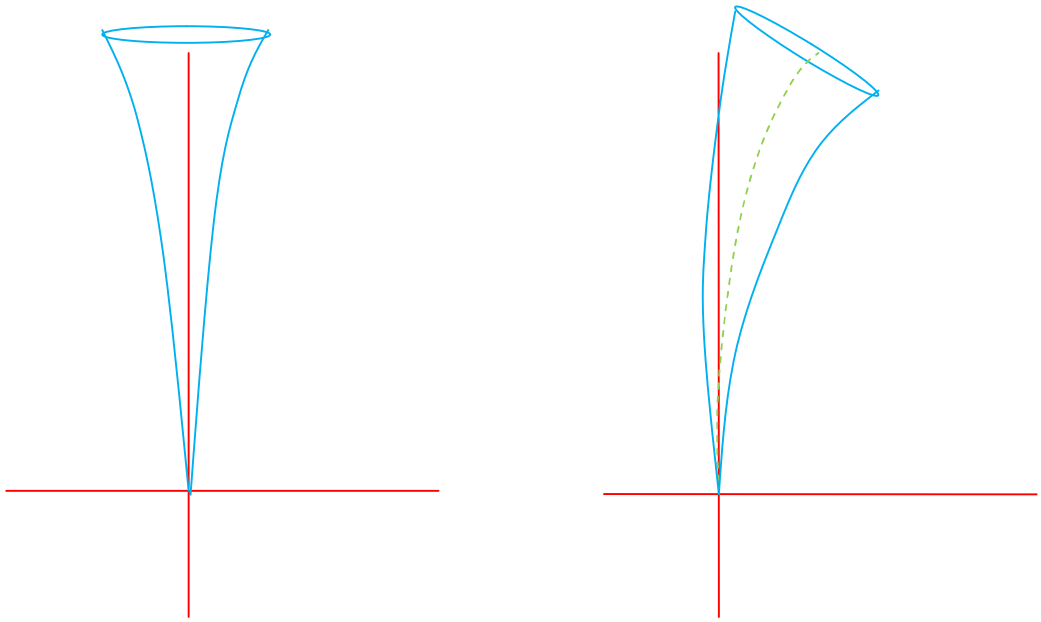


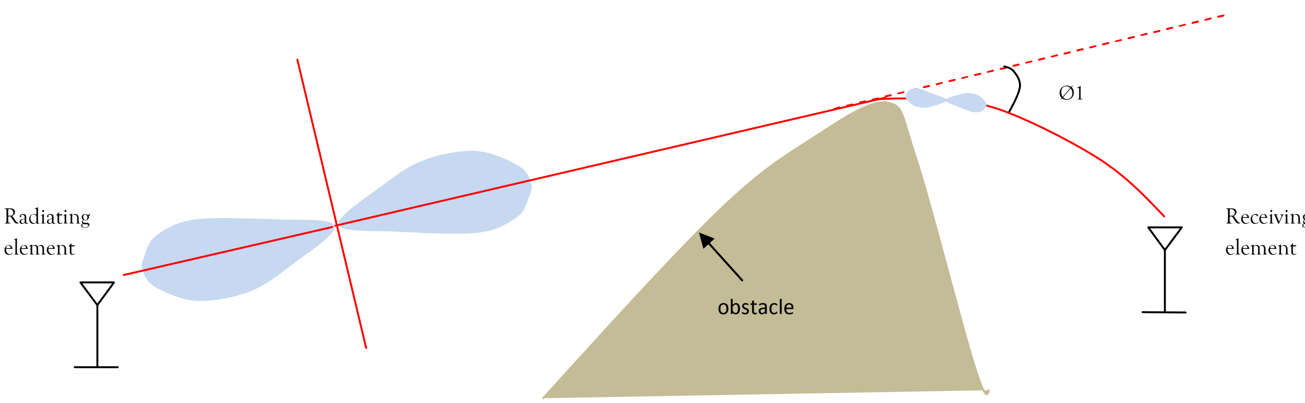
Figure 'b'

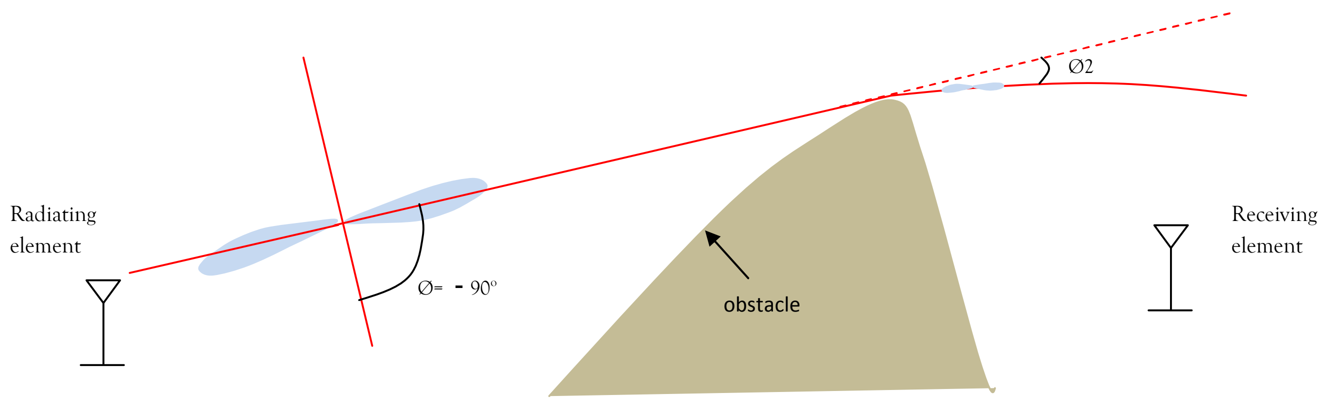
In figure ‘a’ the radiation pattern is symmetrical with respect to y-axis; point ‘p’ radiates equally to the left and to the right. In this case the ‘ spiral cones ‘ will have the y-axis as their axis. In figure ‘b’ the radiation pattern is not symmetrical with respect to the y-axis ; point ‘p’ radiates more power to the right than to the left. Therefore the ‘spiral cones’ will ‘spiral’ to the right as shown in the figure below.



Diffraction depends on radiation pattern and not on frequency

Suppose that the radiation pattern of the radiating element is as shown in the two figures below, with wider beams. According to our knowledge of diffraction so far and Huygens’ principle, the receiving element on the other side of the obstacle will receive an electromagnetic wave depending on the frequency: the lower the frequency the more the EM wave that will be diffracted towards the receiving element from the edge of the obstacle.





According to the theory being proposed in this paper, however, the amount of electromagnetic wave received at the receiving element directly depends on the width of the radiation pattern, no matter what the frequency, with power levels being equal. The wider the beam width the more the diffraction ($\varnothing_1 > \varnothing_2$).

According to our knowledge of physics so far, the extent of diffraction depends on the frequency of the wave. According to the theory presented in this paper, however, *diffraction is independent of frequency if it is possible to produce similar radiation patterns both at very low frequency and at ultra high frequency*. The perceived dependence of diffraction on frequency is only indirect; it is only because radiations at low frequencies are practically always wider than those at high frequencies because of the difficulty to make antennas which radiate sharp beams at low frequencies.

Conclusion

The modification to Huygens' principle has been presented intuitively and is conceptually related with the theory proposed on the spiral propagation of electromagnetic waves and the dependence of diffraction on radiation pattern than on frequency. However, it needs practical tests to be confirmed. The spiral propagation of EM waves follows from closer examination of the diffraction phenomenon. And the dependence of diffraction on radiation pattern (and not on frequency) follows directly. The more isotropic the radiation pattern of the source, the more straight will be the path of propagation in free space. However, where there is an obstacle, waves with more isotropic radiation patterns will diffract the most.

References

1. http://en.wikipedia.org/wiki/Huygens%E2%80%93Fresnel_principle