HOLOGRAPHIC INVESTIGATION OF MULTIPATH INTERFERENCE IN LINE OF SIGHT RADIO LINKS

Khalil H. Sayidmarie & Abdulsattar M. Khidhir
Department of Electrical Engineering
College of Engineering
University of Mosul
Mosul/IRAQ

Introduction

The major problem facing the appropriate usage of line of sight (LOS) radio links is multipath interference. The direct ray usually interferes with reflected, diffracted or refracted rays causing blockage or fading. Holographic techniques could be used to analyze this problem by considering the interference pattern at the receiving end as a hologram. The possibility of utilizing the height-gain pattern as a hologram to determine angle-of-arrival of rays in microwave LOS links was studied by Ja (1). Swingler (2) used similar technique for k-factor measurements and analyzed the effect of a knife-edge obstacle contained in the link. Webster and Scott (3) studied the use of a receiving system with wide aperture vertical array to determine experimentally the angle-of-arrival and amplitude of individual rays during multipath interference. Their technique uses the Fourier transform and it is similar to the holographic method.

This contribution demonstrates the feasibility of using long-wavelength holography with digital reconstruction for the analysis of multipath interference in LOS links.

Theoretical Analysis and Computer Simulations

Figure 1 shows the geometry for a line of sight link where, for simplicity of analysis, two rays are considered. It can be shown that the electric field at the receiving end can be given by:

$$E(y) = \frac{A}{R_1} e^{-j\beta R_1} + \frac{A}{R_2} \Gamma e^{j\phi} e^{-j\beta R_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where $\Gamma e^{j\phi}$ is the ground reflection coefficient, A is a constant and,

$$R_1 = \sqrt{Z^2 + (y - h)^2}, \qquad R_2 = \sqrt{Z + (y + h)^2}$$

Applying the paraxial approximation on R_1 and R_2, it can be shown that E(y) can be written in the form:

$$E(y) = \frac{A}{R_1} \exp\left[-j\beta\left(Z + \frac{h^2 + y^2}{2z}\right)\right]\left[e^{j\beta hy/z} + \Gamma e^{j\phi} e^{-j\beta hy/z}\right] \quad \ldots\ldots (2)$$

The idea of holographic investigation of the multipath effects is to record the received field E(y) in amplitude and phase and then to reconstruct an image from the record. This image represents the field distribution with height at the transmitter side. In the reconstruction process, the quadratic phase (left brackets of Eq. 2) is removed by multiplying E(y) by a conjugate quadratic phase. The result is then Fourier transformed using the FFT algorithm. In this case and if E(y) is sampled at intervals of Δy along a range of height equal to 2a, then the obtained image will have two peaks in the form of sinc functions. The two peaks represent the transmitting antenna and its ground reflected image. It can be proved that the two peaks are separated by a distance 2h or twice the antenna height, and the ratio of their magnitudes will be equal to the magnitude of the reflection coefficient Γ. The image plane extends for $2U = \lambda Z/\Delta y$ and the null-null width of the sinc is equal to $\sigma = \lambda Z/a$.

Figure 2 shows the result of computer simulation of the above idea for a line of sight link of the shown parameters. Amplitude and phase data of the received field were calculated at 40 points ranging from ground level to a height of 60 m. Ground reflection coefficient equal to 0.5 was assumed. The result clearly shows the transmitter and its ground-reflected image. They are separated by 60 m, which is twice the antenna height. The lower peak is 6.5 dB down which corresponds to ground reflection coefficient of 0.473 that is very close to the assumed value of 0.5.

When the facility of recording amplitude and phase of the received field is not available, the magnitude of this field may be recorded using less expensive receiver. In such case and assuming square-law detector, the received field may be written in the form:

$$H(y) = \left| E(y) \right|^2 = \frac{A}{R_1}\left[1 + \Gamma^2 + 2\Gamma \cos\left(\phi - 2\beta hy/z\right)\right] \quad \ldots\ldots (3)$$

Equation 3 represents a Fourier transform hologram which upon Fourier transformation produces an image that corresponds to the field distribution at the transmitter side.

Figure 3 shows the result of computer simulation of the Fourier transform hologram. The same parameters of the first example, as shown, were used but the received power was calculated here. The central peak in the image corresponds to the transmitter while each of the lower two peaks are due to ground reflection. The use of the Fourier transform hologram has duplicated the appearance of ground reflection in the resulting image. The fact that almost half of the image space is redundant here is the penalty for using magnitude recording. Apart from this, the separation of the central and each of the side peaks is equal to 60 m which is also twice the antenna height. Ground reflection is 8 dB down which, according to Eq. 3, shows that the ground reflection coefficient is equal to 0.5.

Conclusions

The feasibility of using long wavelength holography with digital reconstruction for the analysis of multi-path interference has been demonstrated. The technique requires the recording of field distribution with height at the receiver end. After processing, the result shows field distribution at the transmitter end. Valuable information about the link such as position and strength of the sources of multipath rays can be obtained from the result.

References

(1) Y.H. Ja, "Measurement of angles of arrival of waves by microwave holographic techniques," IEEE Trans. Antennas & Propagation, Vol. AP-23, Sept. 1975, pp. 720-722.
(2) D.N. Swingler, "Holographic measurements of k-factor on line-of-sight microwave routes containing knife-edge obstacles," IEEE Trans. Antennas & Propagation, Vol. AP-25, May 1977, pp. 445-446.
(3) A.R. Webster & A.M. Scott, "Angle-of-arrival and tropospheric multipath microwave propagation," IEEE Trans. Antennas & Propagation, Vol. AP-35, Jan. 1987, pp. 94-99.

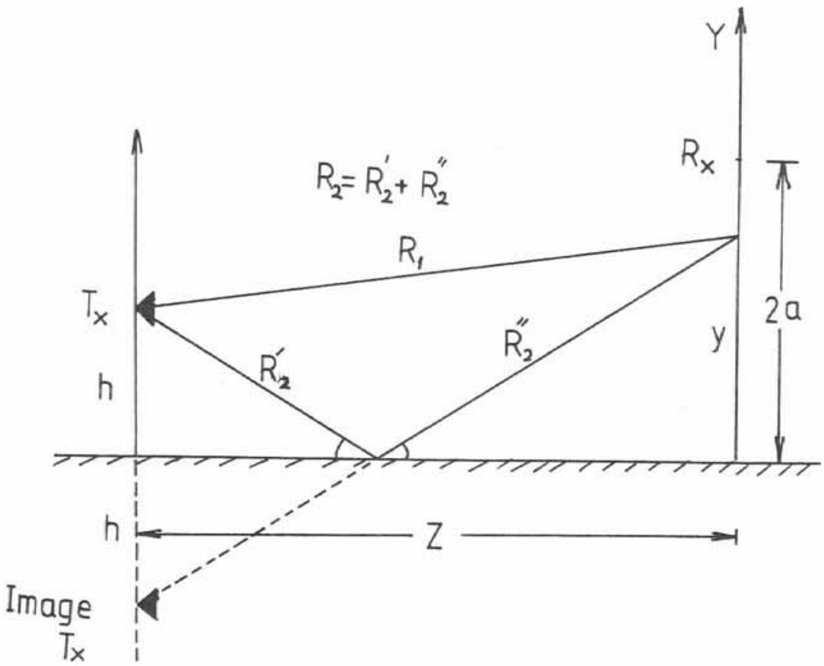

Fig. 1 Geometry for line of sight link showing direct & ground reflected rays.

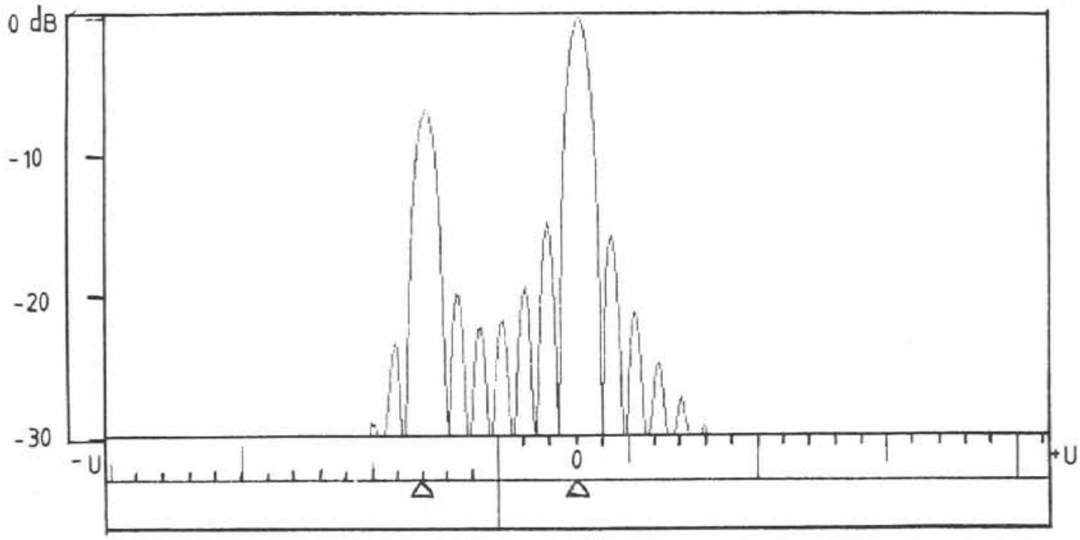

Fig. 2

Result of computer simulation for phase and amplitude recording.
z = 31.5 km, h = 30 m, λ= 1.8 cm.

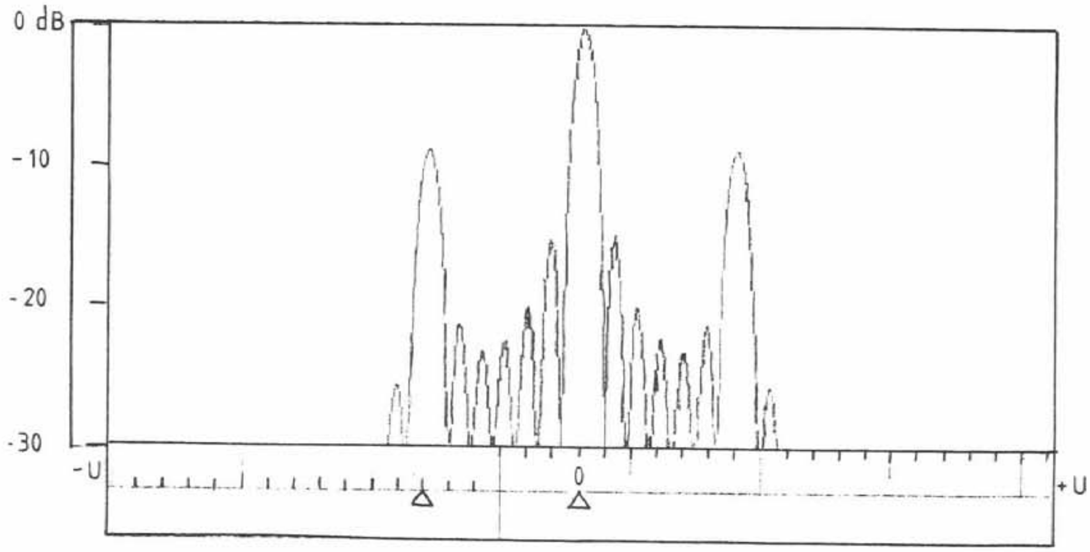

Fig. 3

Result of computer simulation of the Fourier-transform hologram.
z = 31.5 km, h = 30 m, λ = 1.8 cm.