TARGET CLASSIFICATION VIA K-PULSE

Fredric Fok
Department of Electrical Engineering
Faculty of Engineering Science
University of Western Ontario
London Ontario
Canada N6A-5B9

Introduction

The K-pulse concept [1] was formally introduced in 1981. By definition, the late time resonances of a target response are killed by its unique K-pulse. If the wrong K-pulse is used, the late time resonances will not be stopped. The application of K-pulse in target classification or identification has always relied on the visual comparison of this late time behaviour. By defining a likelihood ratio which is a measure of how likely a target response belongs to the guessed target, a number comparison classification strategy is suggested. The likelihood ratio is the ratio of the energy contained within a time period in the late time of the impulse response to the energy of the target response to the K-pulse of the guessed target over the same time period, aspect, polarization and bistatic angle.

Theory

The Likelihood Ratio (L. R.),

$$\text{L. R.} = \frac{\begin{array}{l}\text{Energy within a time period in the late time}\\ \text{of the impulse response of a target}\end{array}}{\begin{array}{l}\text{Energy within the same time period of the target}\\ \text{response at the same aspect, polarization and}\\ \text{bistatic angle to the K-pulse of the guessed target}\end{array}} \qquad (1)$$

If the impulse response comes from the guessed target, the denominator will be zero. By definition, the response of the target to its corresponding K-pulse is time limited. The energy contained outside the K-pulse response duration is zero. Thus, L. R. is infinite. However, if the K-pulse is only an approximation then the L. R. will be finite but large. If the guess is wrong, or the K-pulse of a different target is used in the calculation, the L. R. will be small as the energy reduction is small at late time. Therefore, the strategy for target classification is to compare L. R.'s calculated with the target response to different K-pulses corresponding to different targets. The decision rule is: the larger the L. R. the more likely the target is the target whose K-pulse is used in the calculation of the larger L. R.

Example

In this section, the target classification strategy is used to distinguish between a right-angled bent wire and a straight wire. Both wires are of the same length, diameter and material. The wire length to radius ratio is 2000. Both wire centers are located at the origin. The K-pulses for both wires are generated via the optimization method described in [2]. The straight wire is located along the z-axis. The bent wire is located on the x-z plane, with the +x-axis bisecting the right angle of the bent wire. The L. R.'s are calculated for monostatic scattering of the straight and right-angled bent wire at ϕ=0° θ=45° under different signal power to noise power ratio (S/N) conditions. The time period to calculate the L. R.'s is 4L/c to 5L/c for both straight and bent wire guesses. The results are plotted in Figure 1. For the straight wire target (top figure in Figure 1), the straight wire guess curve is higher than the bent wire guess for S/N>15dB. The larger L. R. is suggesting that the response received is more likely to come from a straight wire than a right-angled bent wire. Similarly, for the right-angled bent wire target (bottom figure in Figure 1), the bent wire guess curve is higher than the straight wire guess for S/N>15dB. Thus, this received response is more likely to come from the right-angled bent wire than the straight wire.

Figure 2 plots the L. R.'s calculated for the straight wire target (top figure) and the right angled bent wire target (bottom figure) in a bistatic scattering case. The wave is incident at ϕ=45°, θ=45° and received at ϕ=45°, θ=135° with θ-polarization. Again, with the straight wire target (top figure in Figure 2), the guess of a straight wire is more likely to be correct down to S/N=15dB, as the L. R.'s are bigger for the straight wire guess. The guess of a bent wire for a bent wire target is also possible down to S/N=15dB with the L. R.'s from the bent wire guess larger than the straight wire guess (bottom figure of Figure 2). The L. R.'s are numerically significantly distinguishable down to S/N=25dB for the two wire targets. Between S/N=15dB and 25dB, the discrimination is still possible but not numerically significant. This is true since the noise is now contributing significantly to the L. R. calculation, making the values of the numerator and denominator of L. R. very close.

Conclusions

A target classification strategy is discussed. Although the targets used in the example are not very realistic, the target classification strategy is able to distinguish two similar targets under very low signal to noise ratio environment. As low as S/N=15dB, the distinction is still possible. Since the K-pulse of a target is an aspect, polarization and receiver location independent, this classification strategy is also shown to have these properties. The distinction under low signal to noise ratio also makes this one number target classification strategy very attractive to radar engineers. Furthermore, the earlier K-pulse classification technique via visual inspection has now been changed to a number comparison scheme.

References

[1] E. M. Kennaugh, "The K-pulse concept", IEEE Trans. Antennas and Propagation, vol. AP-29, no. 2, pp. 327-331, March 1981.

[2] F. Y. S. Fok, D. L. Moffatt, and N. Wang, "K-pulse estimation from the impulse response of a target", IEEE Trans. Antennas and Propagation, vol. AP-35, no. 8, pp. 926-934, August 1987.

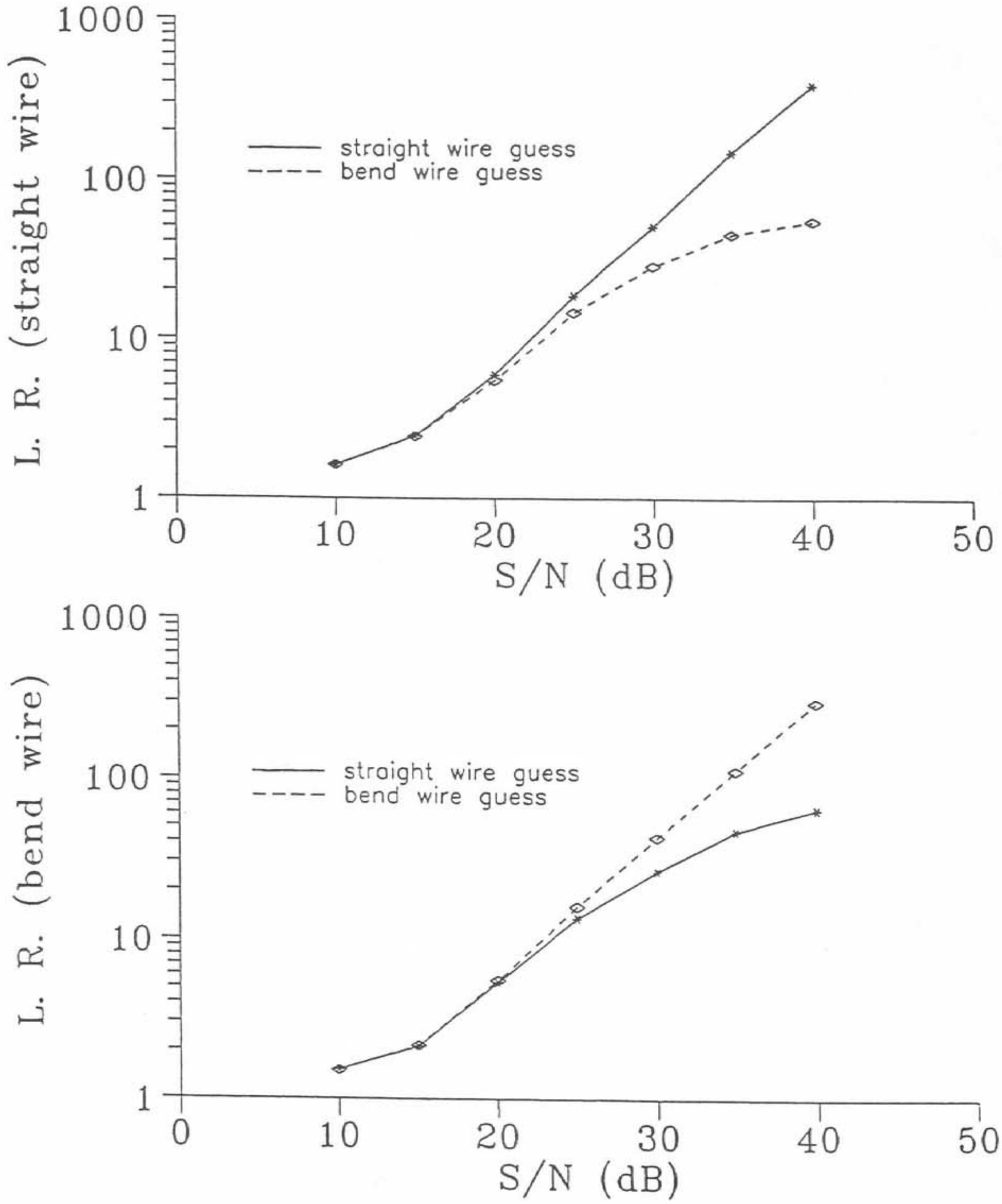

Figure 1 Likelihood ratios of the straight wire (top figure) and the bend wire (bottom figure) for the straight wire guess (solid line) and the bend wire guess (dashed line) under different signal to noise conditions. The responses of the wires are monostatic at $\phi=0°$, $\theta=45°$.

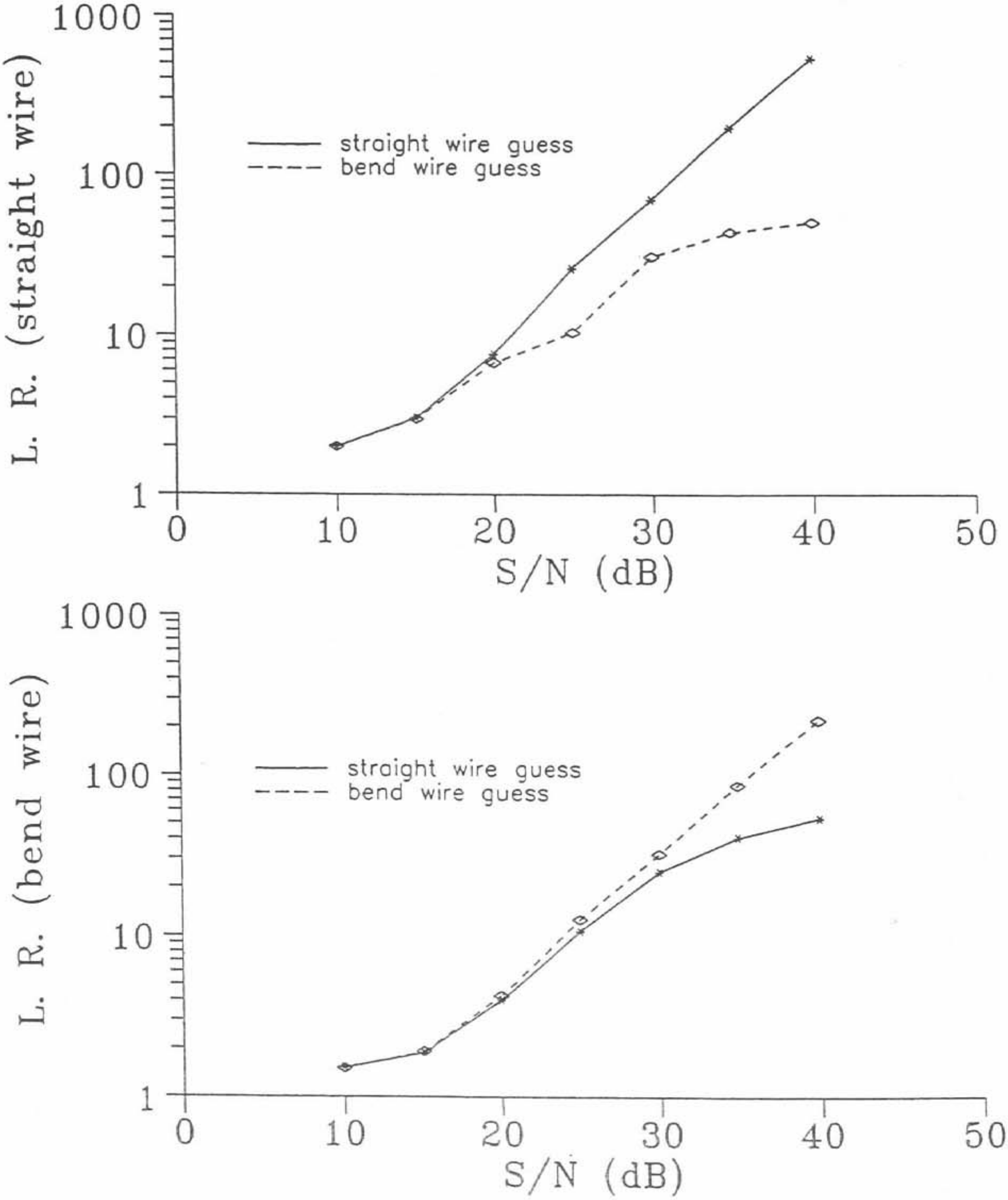

Figure 2 Likelihood ratios of the straight wire (top figure) and the bend wire (bottom figure) for the straight wire guess (solid line) and the bend wire guess (dashed line) under different signal to noise conditions. The responses of the wires are incident at $\phi=45^\circ$ $\theta=45^\circ$ received at $\phi=45^\circ$ $\theta=135^\circ$.