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Anomalous cross-modulation between microwave beams

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ABSTRACT

An anomalous effect in the near field of crossing microwave beams, which consists of an unexpected transfer of modulation from one beam to the other, has found a plausible interpretation within the framework of a locally broken Lorentz invariance. A theoretical approach of this kind deserves to be reconsidered also in the light of further experimental work, including a counter-check of the phenomenon.

Introduction

Some years ago, we reported on an anomalous behavior observed in the near field of crossing microwave beams [1]. The anomaly consisted of an unexpected transfer of modulation from one beam to the other: an effect which could not be interpreted, at least not in a simple way, in terms of the usual electromagnetic framework. Rather surprisingly, it was hypothesized that a model based on locally broken Lorentz invariance, namely, a framework of deformed special relativity (DSR) [2], could be capable of supplying a relatively simple interpretation, in spite of an understandable skepticism that such an assumption could arise [3].

A subsequent work devoted to the same argument, which also included a consideration regarding the superluminal aspect of the wave propagation in near field [4], left the situation unaltered, and concluded that the daring approach invoked for interpreting the results deserved to be considered with much greater accuracy, possibly in the light of further experimental evidence.

Besides confirming the above reported results, the purpose of the present work is just that of supplying further evidence of such an anomaly. In addition, a quantitative test of the theoretical model will be attempted.

The experiments

The experimental set-up adopted is represented by the inset of Fig. 1. The experiment consisted of measuring the signal received at a given distance from the area of interference (or better, of interaction) of the two crossing microwave beams at ~ 9.3 GHz, as emitted by two horn antennas. One beam, or field F_1, was without modulation (c.w.), while the second beam, or field F_2, was modulated by a square wave with a repetition frequency of $\sim$800 Hz. Both beams were derived by the same generator, in order to ensure the coherence of the two fields produced. The modulation signal was detected after the third horn antenna acting as receiver.

The signal, which was measured by a lock-in amplifier tuned at the modulation frequency, as a function of the distance ρ from the F_1 launcher, is represented in Fig. 1. The results obtained, with both beams with vertical polarization, denoted a damping oscillating behavior of the signal around an exponential decay: $S(\rho) \propto \exp(-\rho/\rho_0)$, with $\rho_0 \simeq 53$ cm. In the initial portion, with $\rho \lesssim 23$ cm, the oscillation was rather fast and irregular with a period of a few centimeters, while in the subsequent portion, with $\rho \gtrsim 23$ cm, the period of oscillation suddenly increased up to tens of centimeters. Analogous results, which were reported in Refs. [1,4], were obtained under similar conditions. The behavior in the initial portion could be attributed to an interference between the two beams, while the interpretation in the subsequent region, with a very long period of oscillation, could not be interpreted as an interference effect. The signal evidently disappeared when the modulated field F_2 was stopped; but, and more importantly, it also disappeared when the unmodulated field F_1 was stopped. Thus, the possibility of a mutual influence between the two launchers, as demonstrated in Ref. [1] by measuring the insulation between them which resulted to be of at least ~ 40 dB, was excluded. There, in searching for a different way to interpret the observed behavior, and not simply on the basis of an interference at the position of the receiving antenna, it was hypothesized that the transfer of modulation from one beam (F_2) to the other (F_1) could be interpreted as if a "nonlinear medium" would be situated in the area of the beams's intersection, thus producing a cross-talk or cross

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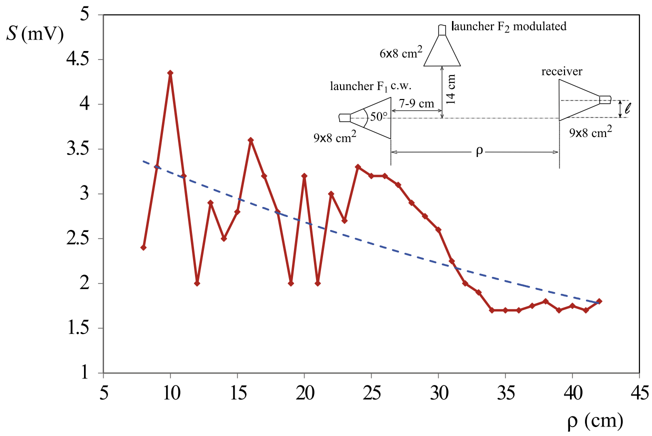

Fig. 1. Signal amplitude measured by the lock-in amplifier connected to the receiver, with F_1 (unmodulated) and F_2 (modulated) in vertical polarization, as a function of distance ρ from launcher F_1, and for an antenna's displacement $l \simeq 2$ cm. In the initial positions, $\rho \lesssim 23$ cm, we observe a fast and irregular oscillation, while in the subsequent $\rho \gtrsim 23$ cm positions, we have a slow damped oscillation. The average of the signal is described by an exponential decay with a length constant $\rho_0 \simeq 53$ cm. The geometry of the experiment is given in the inset.

modulation [5].[1] This represents the anomaly of the phenomenon observed.

In addition to the results reported in Fig. 1, we have performed other measurements of the received signal, by taking the distance ρ at prefixed values (25 and 35 cm) as a function of the displacement l between the F_1 launcher and the receiver (see the inset of Fig. 1). The results obtained are shown in Fig. 2, where the amplitude of the F_1 beam (once modulated and F_2 stopped) vs l, measured for $\rho = 30$ cm, is also reported. From a comparison of the graphs, we evidence that the amplitude of the signal due to the transfer of modulation from F_2 to F_1 was found to be only of 5–7.5% for $l = 0$ as compared with the maximum amplitude of the F_1 beam. In spite of the criticity of the measurements, which produced some uncertainty on the measured values,[2] the overall behaviors were qualitatively confirmed for each case of ρ selected. Of particular interest are the results obtained for $\rho = 25$ cm, which present a typical double-peaked shape where the two peaks are separated by a distance of 4–5 cm. A displacement with respect to the antenna alignment at $l = 0$, of $l = \pm 2$–3 cm corresponds, for $\rho = 25$ cm, to a deviation angle $\alpha \simeq 5^\circ$–7° which, when added to the half-fire angle of the F_1 launcher, $\beta_r = 25^\circ$, gave $\alpha + \beta_r \simeq 30^\circ$–$32^\circ$ for the total deviation angle of the complex wave. This result is nearly coincident with the average deviation angle of $32^\circ \pm 2^\circ$ for which, according to Ref. [6], we obtained the greatest superluminal effect with a maximum shortening of the traversal time. In any case, these results offer other interesting information about the phenomenology that we are studying, even in consideration of a quantitative test of the adopted model.

As a counter-check of the effect, we have monitored the F_2 modulated field by means of a small horn antenna (6×4 cm^2) and relative detector mount (not represented in Fig. 1), placed in front of the F_2 launcher, at a given distance beyond the crossing

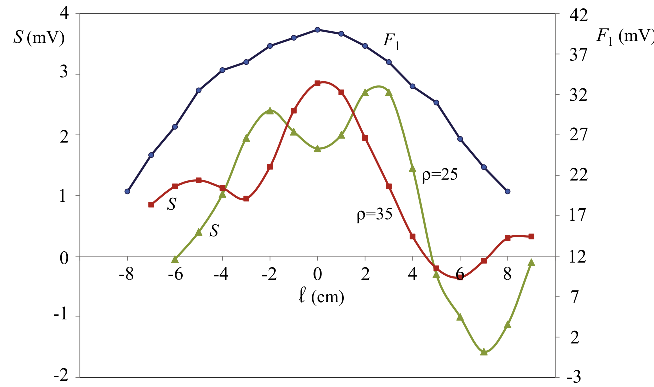

Fig. 2. Signal amplitude measured at fixed values of ρ (25 and 35 cm) as a function of the displacement l between the F_1 launcher and the receiver. The upper curve, with its relative scale, represents the amplitude of F_1 (once modulated and F_2 halted) as measured for $\rho = 30$ cm.

area with the F_1 beam. A signal amplitude of 30 mV was measured in presence of the F_1 c.w. field. When F_1 was stopped, we observed a small variation (a decrease) in the signal of ~2 mV, corresponding to an attenuation of the intensity of ~0.3 dB.[3] Therefore, the order of magnitude of the effect previously observed was roughly confirmed, even if, in this situation its detection is more difficult.

Theoretical model

As previously anticipated, the model that we are considering is based on DSR. We recall that a model of this kind has been adopted in several cases, as e.g. in order to interpret superluminal behavior observed in near-field microwave propagation as reported in Ref. [7]. Indeed, in a subsequent work devoted to these kinds of problems [8], the model based on DSR showed itself to be capable of interpreting data relative to the ratio of the light velocity to the observed signal velocity: $b_s = c/v_s$, measured as a function of the traveled distance ρ; an interpretation that turned out to be even better than the electromagnetic one, which was based on complex waves. In formulas we have:

$$b(\rho) = \left[1 - \frac{E(\rho)}{E_0}\right]^{n/2} \leq 1, \tag{1}$$

with $E(\rho) \leqslant E_0, E_0$ being a threshold energy and n a suitable parameter. When $E(\rho) \to 0, b \to 1$ and we resume the normal luminal behavior. The quantity $E(\rho)$, which is relative to the F_1 beam, is given by

$$E(\rho) = h\nu \exp(-\rho/\rho_0), \tag{2}$$

where $h\nu$ is the photon energy and ρ_0 is the length constant. Because of the behavior observed, we must admit that there is a little increase in the energy $\mathcal{E}$, due to the transfer of modulation from F_2 to F_1 , in the crossing area of the beams. This in turn will produce a δ variation in ρ_0 according to Eq. (2), inverted and modified as

$$\ln\left(\frac{h\nu}{E + \mathcal{E}}\right) = \frac{\rho}{\rho_0 + \delta}. \tag{3}$$

We deduce that the δ increment in ρ_0 for $\mathcal{E} \ll E$, even if very small, is given by

$$\frac{\delta}{\rho_0} = \frac{\rho_0}{\rho}\frac{\mathcal{E}}{E} \tag{4}$$

[1] A right term suitable to produce the transfer of modulation, from one beam (F_2) to the other one (F_1), could be constituted by a third-order component of this type (see Table 10-2 in Ref. [5]) $E_1^2 E_2 \sin(2\omega_1 - \omega_2)t$, with E_1 and E_2 being the field amplitudes of F_1 and F_2, respectively. The spectrum of F_1 c.w. consists only of $\omega_1 \equiv \omega_0$ of the carrier, while the one of the modulated F_2 consists of $\omega_2 \equiv \omega_0$ and $\omega_0 \pm \Omega$, where Ω is the modulation frequency. Therefore, we have that $2\omega_1 - \omega_2 = \omega_0$ and $\omega_0 \mp \Omega$, which reproduces the same spectrum of F_2 field, to be found in the F_1 beam.

[2] The S values reported in Fig. 2 are obtained, for each ρ, as an average of two determinations, with an accuracy of about 10% of their maximum values.

[3] This means that a term like the one described in the FootNote 1 can operate a positive transfer of energy between the two beams in both directions.

and that it can produce an appreciable signal if increment $\mathcal{E}$ is modulated. On the other hand, in situations of large values for ρ_0, so that we have $E(\rho) \approx h\nu$, we obtain another approximate relation

$$\left|\frac{\mathcal{E}}{E}\right| \simeq \frac{\rho}{\rho_0}. \quad (5)$$

From this we deduce that the observation of the phenomenon is less evident with increasing ρ_0 [9].

In our case, by assuming that the ratio $\mathcal{E}/E$ is given by the ratio of the relative intensities at $l = 0$ in Fig. 2,[4] namely $\mathcal{E}/E \simeq (2-3)/40$, and by assuming $\rho_0 \simeq 53$ cm as in Fig. 1 and $\rho \simeq 30$ cm, from (4) it seems that $\delta/\rho_0 \simeq (7-11)\%$, i.e. $\delta \simeq (4-6)$ cm, which appears to be a reasonable one.

Therefore, it seems that the above interpretation appears to be capable of describing the behavior observed, in a more convincing way than what has been asserted in previous works [1–4], where other concomitant effects were not ruled out. By the way, these results lead to introduce a new deformed metric able to describe this phenomenon [2,3].

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[9] In fact, in an attempt to observe the phenomenon with laser beams, a very small effect was obtained. See: Allaria E, Meucci R, Mugnai D, Ranfagni A, Ranfagni C. Mod Phys Lett B 19;2005:1403, where ρ/ρ_0 was estimated to be less than 10^{-3}.

[4] Given the quadratic character of the detectors, the absolute value of the revealed signal is proportional to the power, or intensity of the field.