STUDY OF SUBMILLIMETER WHISKER STRUCTURES BY MICROWAVE EXPERIMENTAL SIMULATION AND THE GEOMETRICAL THEORY OF DIFFRACTION

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ABSTRACT

This paper describes two complementary studies of whisker structures used in submillimeter detectors. The radiation patterns can be determined both from measured surface currents and the geometrical theory of diffraction. Particular attention has been given to the effective length of the structure and the influence of the geometry.

In the submillimeter wavelength domain, detectors and mixers have to be directly coupled to coherent beams. This coupling is achieved by focusing the beams on a structure feeding the non linear device. For devices such as MOM, Schottky or Josephson junctions, whisker structures, derived from wires by cheminal etching, provide good sensitivities even at short wavelengths. The complete electromagnetic treatment of the coupling of such structures to focused beams has been given [1]. It has been shown that the power transfer coefficient between the incident beam and the device is simply related to the input impedance and the radiation characteristic of the structure in the emitting situation. The optimal coupling is obtained when the input impedance is the complex conjugate of the junction equivalent impedance and when the radiation pattern matches the spatial field distribution of the incident beam.

In order to perform quantitative calculations of the power transfer coefficient, it is then necessary to know the radiation pattern. For the considered wavelength domain, the whisker structure can be often considered as a rather thick and long (compared to the wavelength) conical antenna, with a cylindrical prolongation. The radiation characteristic can be deduced from the knowledge of the current on the antenna. Rigorous analytical or numerical determination of the currents is very difficult. For instance, moment methods applied to integral equation approach are practically intractable for such structures. Approximating the current with a good accuracy is not easy. Even considering that the current can be described by means of a pure travaling wave [2], there exists the fundamental problem of determining the effective length of the structure outside which the currents can be assumed to be zero. Some contradictory comments have been made on this subject [3] [4] : is the effective region restricted to the conical part, or not ? What is the influence of bending the wire in the cylindrical part ?

In order to answer these questions, two complementary studies have been done. The first one is based on a microwave simulation of the infrared structures. An experimental set-up (Fig. 1), working in the centimeter range (X-band), allows the measurement of the surface current and the near field. The measured values

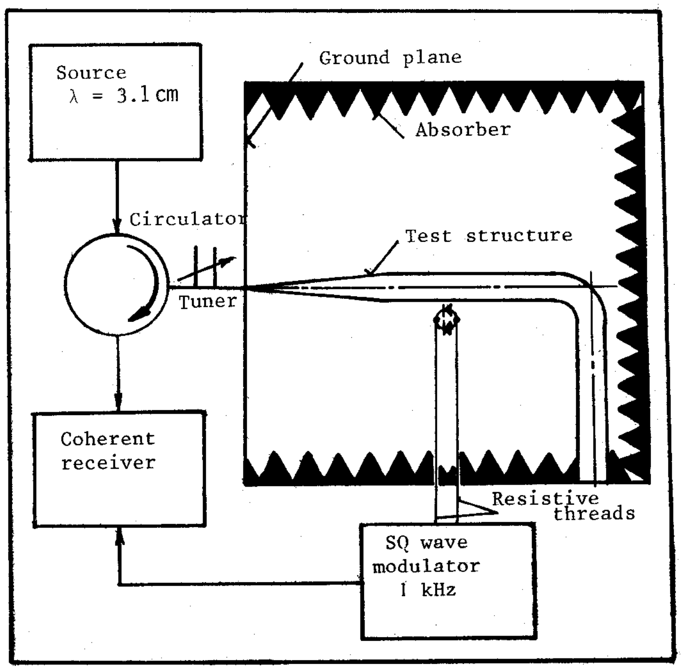

Fig. 1 : Instrumentation for measurement of surface current with small modulated loop.

of the current can be included in computer programs for calculating the radiated field. In order to reduce the perturbation due to the coaxial line between the probe and the receiver, the modulated-scattering method is used. For instance, the effect produced by the etching process on the surface current density is illustrated on Fig. 2 and Fig. 3 for a conical structure the length of which is 8 λ and the diameter approximately 2 λ . The real part of the current is given indicating that the usual linear phase variation is justified. For the non linear profile a large peak exists at the junction with the cylindrical prolongation. Such differences affect the fine structure of the radiation pattern.

The second study uses the geometrical theory of diffraction (GTD). By means of diffracted rays generated at the antenna discontinuities it is possible to calculate the radiation pattern. The method offers a clear insight into the influence of the geometrical parameters of the structures and in particular the cylindrical prolongation of the antenna. It then becomes possible to know at what distance bending the wire is of negligible importance.

The antenna consists of two cones, each surmounted by a cylinder of length d variable between 0 and ∞ , see figures 4 and 5.

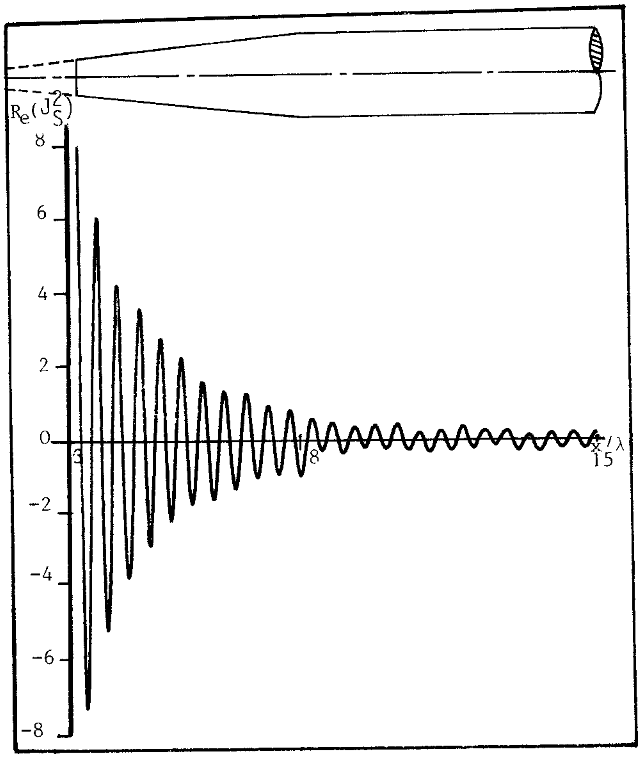

Fig. 2: Real part of the square of the surface current on an antenna with linear profile.

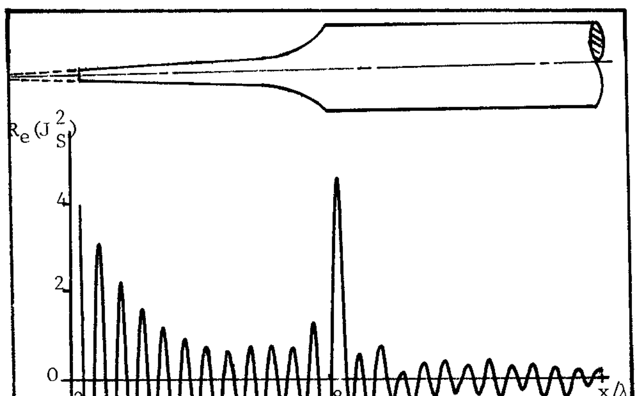

Fig. 3 : Real part of the square of the surface current on an antenna with non linear profile due to etching process.

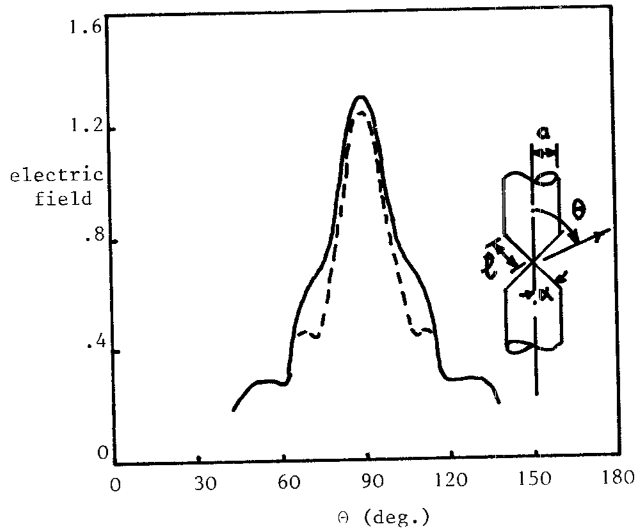

Fig. 4 : Maximum field and maximum gain.

—— α = 68° yields maximum field at Θ = 90°.
– – α = 72° yields maximum gain
kl = 32.36 in both cases.

The source is a generator at the centre supporting TM waves. The infinite antenna of figure 4 has a radiation pattern determined by three rays, a direct ray coming from the generator region, and two rays diffracted by the two discontinuities. The antenna with finite cylinders supports in addition three doubly diffracted rays, see figure 5. For the case d = 0 there are three singly

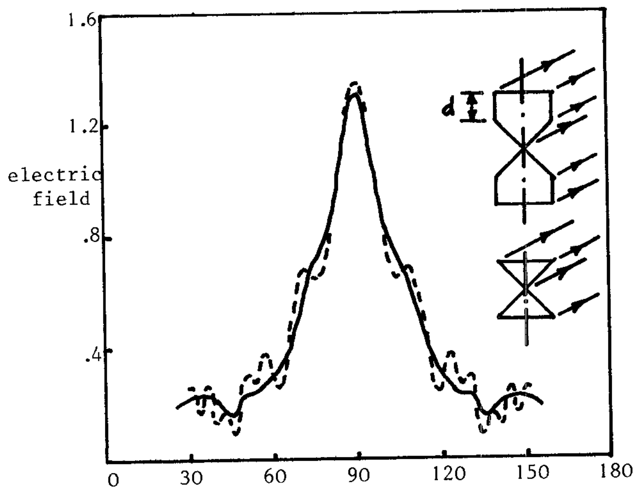

Fig. 5 : Influence of cylinder length d.

—— d = ∞
– – d = 0
α = 70°, ka = 35.9 in both cases.

diffracted rays, see figure 5. The diffracted fields are calculated using the diffraction coefficients of PATHAK and KOUYOUMJIAN [5].

Close agreement has been found in cases where previous results were available [6] , see figure 6. The main conclusions are as follows :

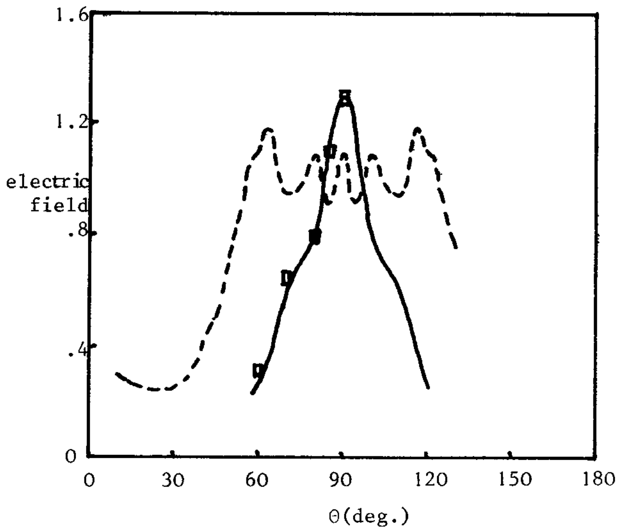

Fig. 6: Influence of half angle .
—— α = 70°
– – α = 45°
ka = 35.9 in both cases
values calculated from Jasik [6]

1. - For the antenna with infinite cylinders :
(i) For α → 90° the field maximum is at Θ = 90° and is moderate in value. Directivity is poor.

(ii) As α decreases the field maximum remains at Θ = 90°. Its value and that of the directivity increase and pass through maximum values. The directivity is maximum for a value of α greater than that at which the field is maximum, see figure 4.

(iii) As α decreases further the single main lobe separates into many , symmetrical about Θ = 90° with the outer lobes largest, see figure 6. As α approaches 0° the outer lobes are much larger than those in between, but the present theory ceases to be applicable due to the presence of caustics at Θ = 0° and 180°.

2. - For the antenna with finite cylinders :
(i) For large values of α (> 45°, say) the cylinder lenght has little influence on the radiation pattern, see figure 5.

(ii) For smaller values the present theory ceases to be applicable, because the ends lie in the transition region of the field diffracted from the cone-cylinder junction, but it is expected that the end effects, and thus the cylinder lengths, are important.

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