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MOMENT METHOD ANALYSIS OF VHF ANTENNAS ON VEHICLES
ON AN IMPERFECT GROUND.

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D. J. Brammer

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MOMENT METHOD ANALYSIS OF VHF ANTENNAS ON VEHICLES ON AN IMPERFECT GROUND

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INTRODUCTION

The study of vhf vehicle antennas is complicated by the irregular vehicle which is typically of the order of a wavelength and the imperfectly conducting ground on which the vehicle stands. This memo presents a treatment of idealized armoured vehicles fitted with whip antennas standing on an imperfectly conducting ground based on the 'Moment Method' for the vehicle and including a Sommerfeld based treatment of the ground. The 20-76 MHz vhf band is of interest but since the investigation showed that ground effects are more important at the lower part of the band attention was focussed on this.

Idealized versions of the armoured vehicles of interest were examined. Fig 1 shows the simplest - a rectangular box; Fig 5 shows a shape nearer the true vehicle. The idealized models are fitted with 2M whip antennas in the position used in practice. The vehicles are 8M long and are supposed to be supported by insulating tracks 30cm above ground. The numerical analysis was supplemented by some experimental work carried out at 1/30 scale in an anechoic chamber.

MOMENT METHODS

There are many variations of the Moment Method ranging from the basic formulation to details of the numerical analysis. A wire grid modelling of the surface of the vehicle is the most common approach. The wire model of Fig 1, which includes 280 segments was the subject of the first investigation. The methods tried were:

- i Pulse current, point matching (collocation).
- ii Piecewise Sinusoidal with Galerkin Matching (PWSG) (1).
- iii A 3 term (dc, sinusoidal, co-sinusoidal) current expansion on segments with current and slope of current continuity at segment junctions as used by Burke and Poggio (2).
- iv A simple surface patch technique (2).

In the first 3 (wiregrid) methods the Electric Field Integral Equation is used, this implies the use of the tangential electric field in the boundary condition whereas in the surface patch technique the Magnetic Field Integral Equation is used with the magnetic field boundary condition. In the wiregrid analysis a difficulty occurs with the diameter of wire used in the grids modelling surfaces. The diameter chosen was in terms of equivalent surface area selected by comparison of experimental results and calculations of the polar patterns of spheres with whip antennas. The first 2 programs were written locally. The second pair were available on the program NEC (2) written at the Lawrence Livermore Laboratory of the University of California.

Fig 2 shows the polar diagram of the vehicle model of Fig 1 at 35 MHz as calculated by the various moment method systems. The first three methods, pulse current point matching, the piecewise sinusoidal with Galerkin matching and the 3 term NEC, all use 288 segments. The patch method used patches plus wire antenna segments. Also shown is an experimental curve obtained in an anechoic chamber with a continuously skinned box scaled 1/30. It can be seen that all methods give reasonably good results; the pulse current method being slightly poorer. The piecewise sinusoidal method was rejected since on modelling a surface with a wiregrid for a given number of segments, the piecewise sinusoidal method involves an increase in the number of unknowns by a half. The solution of a system of simultaneous equations is central to the moment method and increasing the number of unknowns by a half increases the number of operations by a factor of 3.4. The NEC 3 term wiregrid program was used for the subsequent work. The program contains many options including the facility for inserting a reflexion coefficient approximation imperfect earth.

The moment method solution gives as a primary product the current distribution on the conductor system and therefore estimates the input admittance. Generally it is found that the susceptance which is concerned with near fields near the feed point is difficult to estimate. Table 1 contains estimates of input impedance and is compared with network analyser measurements on the 1/30 scale model.

TABLE 1

Freqn MHz	Impedance Ohms	
	Experimental	Wiregrid NEC
30	26.1 - 61.5 j	34.4 - 87.0 j
35	48.8 + 3.0 j	50.5 + 5.6 j
40	61.5 + 79.0 j	71.5 + 87.3 j

The results are stable with respect to changes of segment length as is shown by a series of calculations at 35 MHz.

TABLE 2

Segment Length	Impedance Ohms
$\lambda/20$	50.5+5.6j
$\lambda/28$	53.1+4.5j
$\lambda/48$	57.3+2.6j

This indicates that the current continuity algorithm used is reliable.

IMPERFECT GROUND EFFECTS

In mobile vehicle to vehicle communication the vertical field at the ground is the important parameter. The presence of the ground has two effects on this, in the first place the current distribution on the vehicle is affected by the ground, in the second place given a current distribution on the vehicle the far field is affected by ground reflection. In the moment method the field due to the current in one segment is to be calculated at a match point usually at the mid point of another segment. In the present problem the distance involved and that of segment and match point from the earth's surface are fractions of a wavelength. This makes use of Sommerfeld's theory for fields near the earth's surface necessary. When the observation point and current element are both on the same side of the interface (in air) the field is obtained in terms of the U and V integrals together with source and image terms (Baños (3)).

$$U_{22} = \int_{-\infty}^{\infty} \frac{e^{\gamma_2(h+z)}}{\gamma_1 + \gamma_2} H_0^{(1)}(\lambda\rho) \lambda d\lambda$$

$$V_{22} = \int_{-\infty}^{\infty} \frac{e^{-\gamma_2(h+z)}}{k_1^2 \gamma_2 + k_2^2 \gamma_1} H_0^{(1)}(\lambda\rho) \lambda d\lambda$$

Where ρ is the separation of source and observation points projected on the surface of the earth and $(h+z)$ is the sum of the heights of these points above the earth (or the vertical separation of the observation point from the source point image in the earth's surface). The suffix 1 refers to the ground and 2 to the air above, k is the propagation constant.

$$\gamma = (\lambda^2 - k^2)$$

and $H_0^{(1)}$ is the Hankel function.

If calculations of U_{22} and V_{22} were carried out for each estimation of the field an intolerable computer processor time would be taken. It was pointed out by Brittingham (4) that since with source and observer points on air the field is a function of $h+z$ and ρ a two dimensional interpolation can be used. In the present work the reflection coefficient method of introducing the earth is used and the fields obtained are corrected by a two dimensional interpolation from a precomputed and stored table of correction factors derived from the Lytle and Lager method of applying the Sommerfeld theory (5).

Table 3 gives the relative timing for the calculation of the 5 field components,

$$\begin{matrix} E_r^V & E_z^V & E_r^H & E_z^H & E_\phi^H \end{matrix}$$

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TABLE 3

PROCESSOR TIME

Free Space	- 2 msec
Reflection Coefficient	- 5.5 msec
Sommerfeld	- 2.5 sec
Interpolation	- 9.5 msec

The wiregrid model of Fig 1 was analysed with the structure 0.3M above ground (insulating tracks are assumed) with constitutive parameters $\epsilon_r = 9.0$, $\sigma = 0.01S$ firstly at 35 MHz. The resulting polar diagram on the earth's surface is shown in Fig 3 and there is little difference between the results if current distribution is calculated using the Sommerfeld treatment, the reflection coefficient treatment or with no earth at all. The chief effect of the earth is noticed in calculating the polar diagram from the current distribution and the asymptotic Norton theory is required.

When the same calculations are repeated at 20 MHz a greater difference is noted, the case for the full Sommerfeld treatment is more noticeable in Fig 4.

To show that the results do not depend on the unrealistic vehicle model used and that the current system is not restricted to the top of the vehicle, the more realistic model of Fig 5 was also analysed. Again the results in Fig 6 show that at 35 MHz the polar diagram at the earth's surface again chiefly depends on the use of the Norton asymptotic theory; the method of calculating the current distribution not being important.

CONCLUSION

It is concluded that the Sommerfeld ground treatment is only important at the very lowest part of the vhf band when calculating coverage. When the full ground treatment is required substantial savings in computer processor time are to be found by using the interpolation method.

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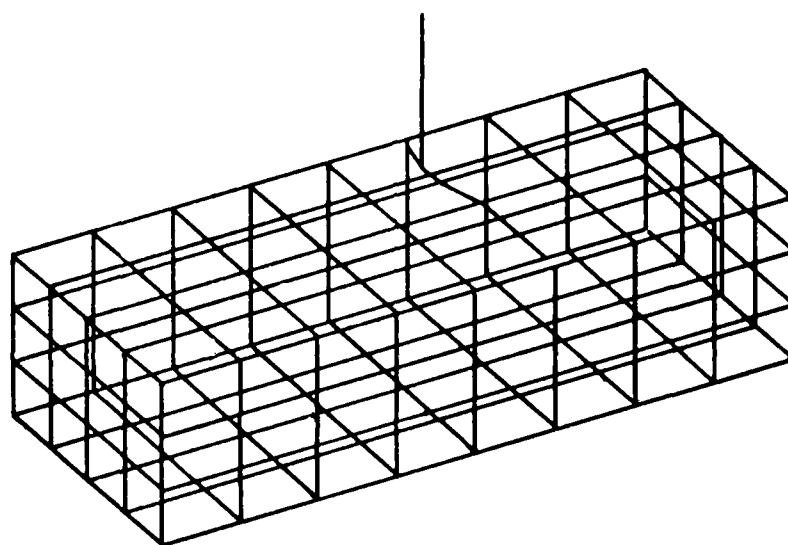
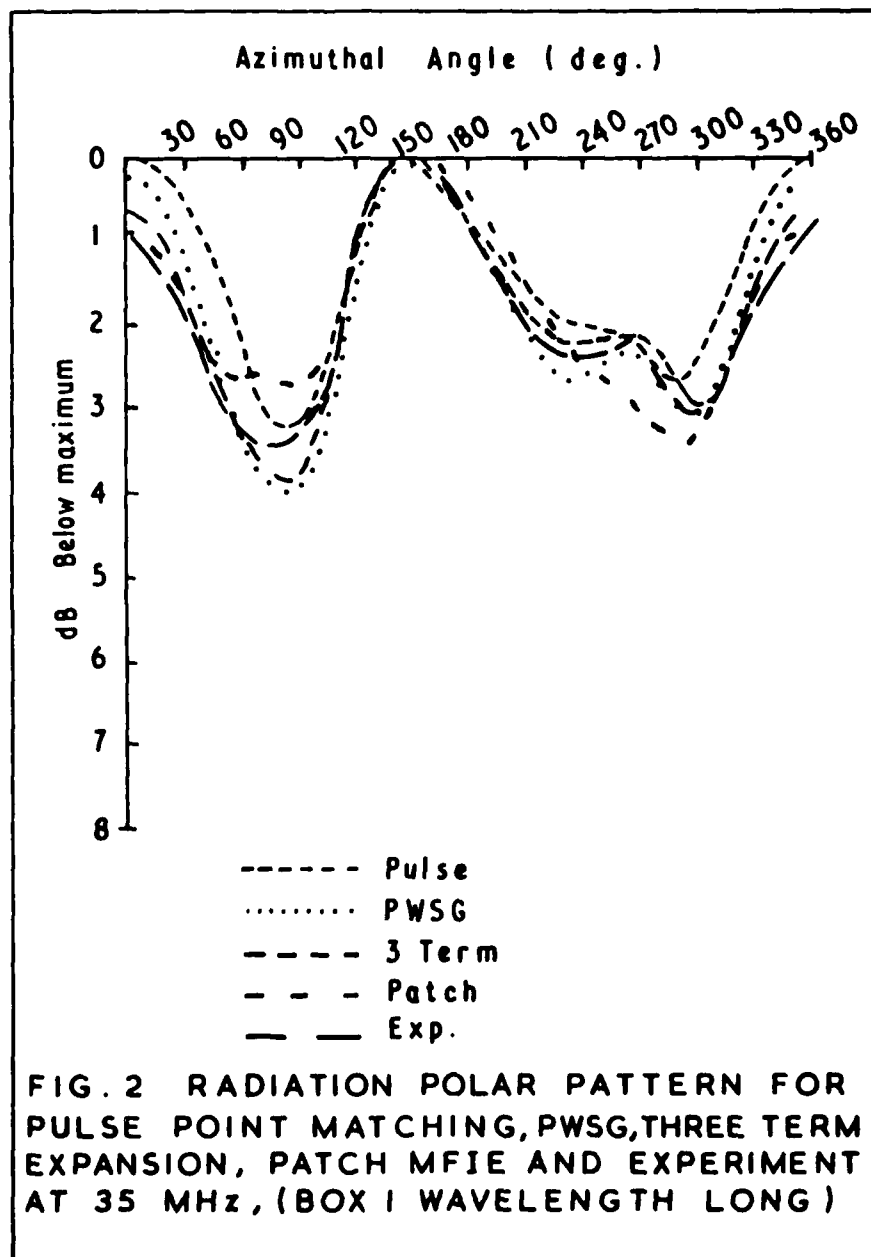
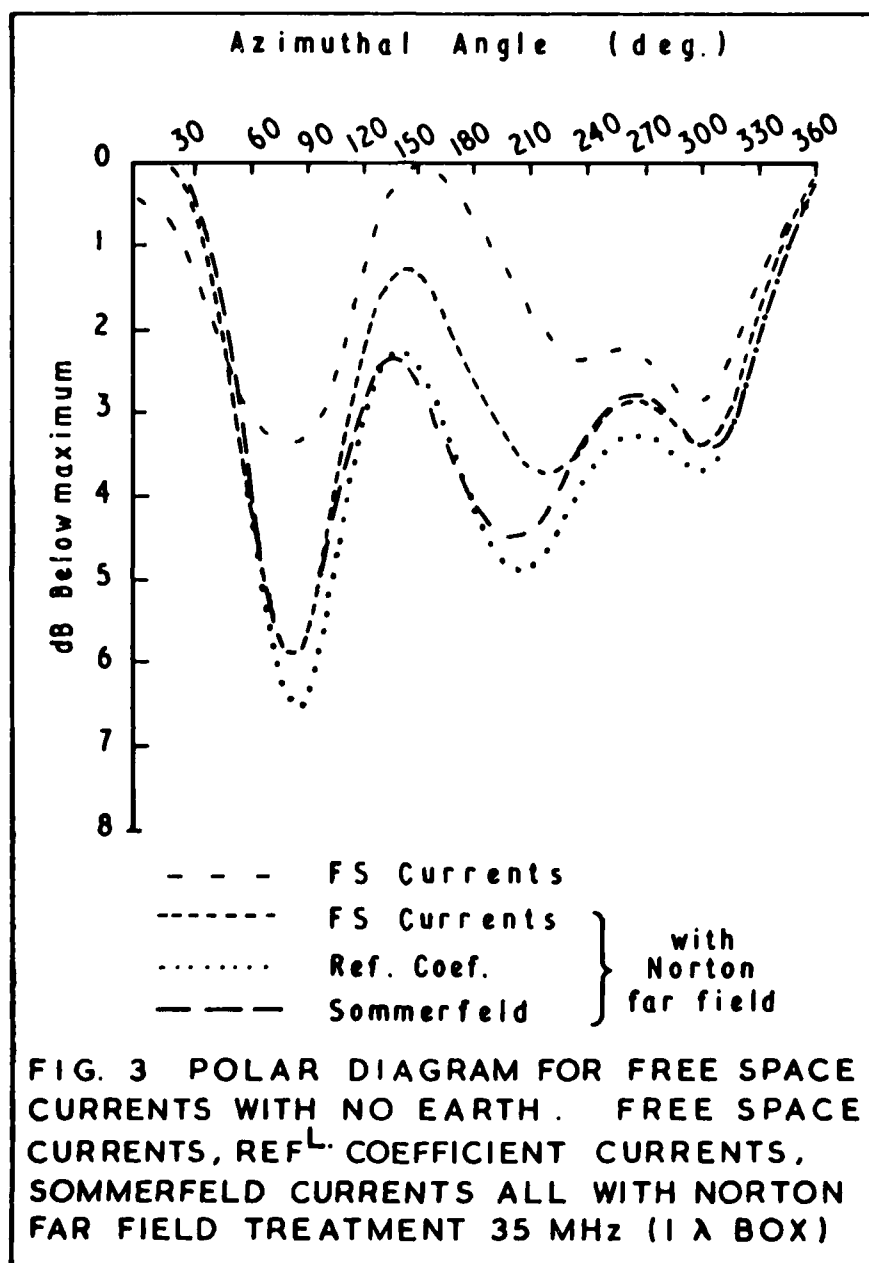
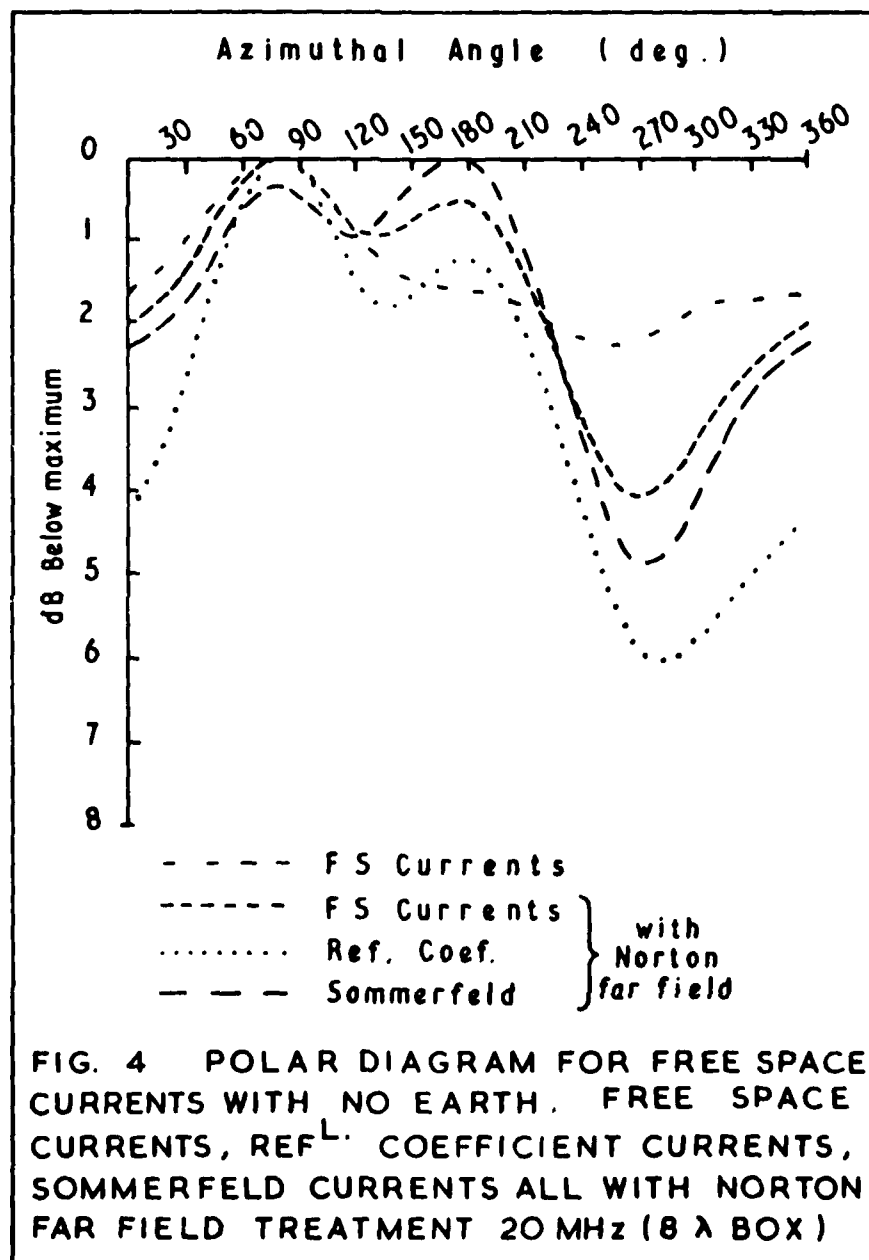


FIG. 1 WIREGRID BOX REPRESENTATION
OF ARMoured VEHICLE







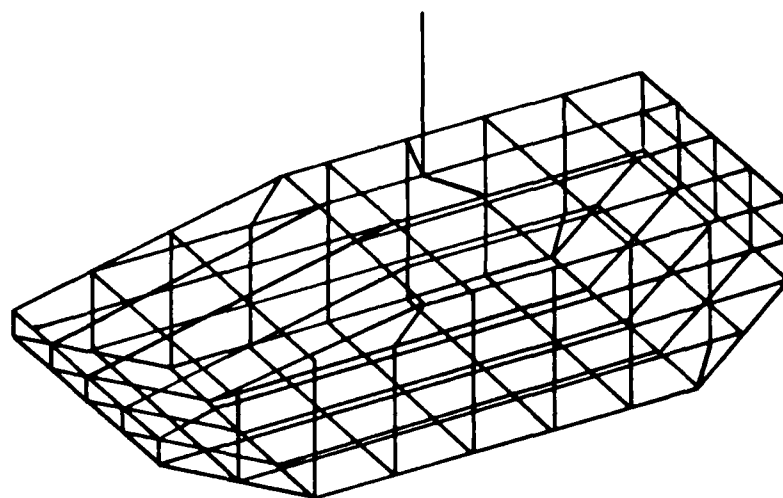


FIG. 5 SECOND WIREGRID REPRESENTATION
OF ARMoured VEHICLE

