THE FULL HYBRID FIELDS AND NETWORK PARAMETERS OF TRANSVERSE AND LONGITUDINAL METALLIC STRIPS IN INSET DIELECTRIC GUIDE, (I.D.G.)

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Abstract.

Arrays of metallic strips on the air-dielectric interface of an Inset Dielectric Guide, I.D.G., allow the simple fabrication of planar arrays that demonstrate pure polarisation and good efficiency and input match.

This contribution presents, for the first time, a full hybrid characterisation of both transverse and longitudinal strips, producing vertical and horizontal polarisation respectively, investigating both the frequency and dimensional sensitivity of the near and far fields.

In particular, we demonstrate the significant near field contribution of the radiation modes, which has important consequences for accurate design of arrays.

Introduction.

Using metallic strips on the air-dielectric interface of the Inset Dielectric Guide, I.D.G., allows the simple construction of planar millimetric arrays, (1). Transverse and longitudinal strips produce vertically and horizontally polarised radiation respectively and, moreover, such arrays feature pure polarisation, good input match, efficiency and near field isolation between parallel arrays in 2D configurations.

The building block of such arrays, the single strip shown in figure 1, was previously analysed using L.S.E./L.S.M. approximations to the radiation field, (2,3). However, whilst the L.S.E. approximation is quite adequate for the deep slot I.D.G., the L.S.M. approximation fails to correctly model the behaviour of the longitudinal strip.

Meanwhile, we have been able to develop the compete hybrid spectrum of the I.D.G., including a continuum of modes that represents radiation from the structure and subsequently, the utility of this spectrum has been demonstrated by an, experimentally verified, analysis of feed transitions from rectangular metallic waveguide, (4,5).

The availability of this novel part of the spectrum has allowed us to reconsider the problem of radiating strips using a rigorous hybrid formulation. We present results for both transverse and longitudinal strips, detailing the variation of the radiation patterns and the Y- and S-parameters with both frequency and strip dimensions.

Theory.

The complete hybrid spectrum of the I.D.G. has been developed using a dyadic characteristic Green's function, (4), although alternatively, a conceptually simpler mode matching approach, yielding identical results, may be adopted, (5).

From this mode spectrum a dyadic electric Green's function, $\underline{\underline{G}}_E(\underline{r},\underline{r}')$, relating the scattered electric field to the source current is constructed, giving due consideration to its validity in the source region, (6).

The electric field incident upon the strip, $\underline{E}_i(\underline{r})$, excites a current, $\underline{J}(\underline{r})$, and subsequently a scattered electric field, $\underline{E}_s(\underline{r})$, such that the total electric field tangential to the strip vanishes, ie;

$$y \times (\underline{E}_i(\underline{r}) + \underline{E}_s(\underline{r})) = \underline{0} \qquad (1)$$

Introducing the Green's function results in an integral equation for the strip current.

This integral equation may be solved using Galerkin's method and subsequently, the scattering parameters obtained from the Green's function. Similarly, the far field radiation patterns may be efficiently determined by applying saddle point integration techniques to the Green's function representation of the radiation field.

Application of Galerkin's method requires the discretisation of the strip currents. For the transverse strips it is reasonable to assume infinitesimal width, thus reducing (2) to a scalar equation. The remaining current component, J_x, being expanded using weighted Gegenbauer polynomials that intrinsically model the expected order of zero at the ends of the strip. For the longitudinal strips, a full vector integral equation is retained allowing the strips to have a significant width and in fact including the case of patches. Again the transverse dependences of the current components are expanded using the appropriate order weighted Gegenbauer polynomials and the longitudinal dependence by sine and cosine terms. This latter choice, although resulting in a slower convergence, is computationally efficient due to the term $e^{-j\beta|z-z'|}$ appearing in the Green's function.

Results.

i) Transverse strips

It is observed from figure 2 that there is an almost linear relationship between strip length and both the radiated power and the reactive power storage in the near field, the latter being inductive which is consistent with the quasi-L.S.E. nature of the deep slot I.D.G. This simple behaviour, coupled with the relative insensitivity of the parameters to frequency

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1992 IEEE MTT-S Digest

above 9GHz bodes well for the design of arrays. However, not only is there a noticeable change in the behaviour of the network parameters below 9GHz, but is is also observed in figure 3 that the direction of the main lobe in the radiation patterns in the z-x plane varies significantly with frequency. Both these phenomena may be explained by considering the strength with which each radiation mode couples to the strip current. Examination of the transverse mode functions reveals that , at a given frequency, certain narrow bands of the radiation spectrum resonate under the strip, thus giving rise to maxima in the radiation patterns that are offset from broadside and in fact, often constitute the main lobe. It is found that resonances can only occur in certain frequency ranges. For example, the first resonance occurs between 10.2GHz and 14.2GHz producing a beam that scans from broadside to endfire between these limits. This behaviour is then repeated with the appearance of the next order resonance.

ii) Longitudinal strips.

It is only feasible here to present a selection of the results obtained for the longitudinal strips, more shall be given in the presentation.Figure 4 shows the variation with length of the S-parameters of a 2mm wide strip operating in the X-band. In general, two types of behaviour may be observed. Firstly, a 'fast' variation with length of period 25mm and secondly, a slow variation that gives maximum radiation for strips with lengths in the vicinity of 30mm. The most surprising feature however, are the extremely high levels of radiated power, up to 90% of the input power. These general characteristics have been investigated experimentally, although the results are rendered qualitative by the high levels of radiation coupling into the calibrated ports and thus distorting the measurements. However, the 'slow' and 'fast' variations and high levels of radiation are apparent.

The 'fast' variation with length is consistent with the excitation of the quasi-T.E.M. mode of the microstrip loaded I.D.G. , (7), however it is clear that such a monomodal model of the strip is inadequate. To explain the 'slow' variation, we observed that the same 'fast/slow' variation has previously been reported for interacting steps in planar dielectric guide, (8), and that, if the intervening length of guide is totally removed then only the 'slow' variation remains. Clearly in this case coupling by the radiation modes seems to be solely responsible for this effect. It is suggested therefore, that the slow variation with strip length is due to significant coupling by the radiation modes excited at both ends of strip.

The far field patterns, shown in figure 5, clearly illustrate the transition from the behaviour of a short dipole to that of a leaky-wave structure radiating at an angle to the surface of the guide.

In general, as the width of the strips is increased, (up to half that of the guide), the amplitude of the 'fast' variation decreases. This is not surprising, due to the increasing dissimilarity between the fundamental modes of the I.D.G. and those of the microstrip loaded I.D.G.

Conclusion.

We have presented a rigorous hybrid analysis of radiating rectangular strips in I.D.G. using a novel continuum of hybrid radiation modes. Both network parameters and radiation patterns have been obtained for the two different strip orientations. The radiation patterns of the transverse strips exhibit an unusual beam squint which may be explained by considering the coupling between each of the radiation modes and the strip.

The results for the longitudinal strips clearly demonstrate the significant near field contribution of the radiation modes, which not only give rise to high levels of radiation from moderate length strips, but also strongly couple both ends of the same strip. This latter feature has important consequences for the accurate design of arrays and is currently under further investigation.

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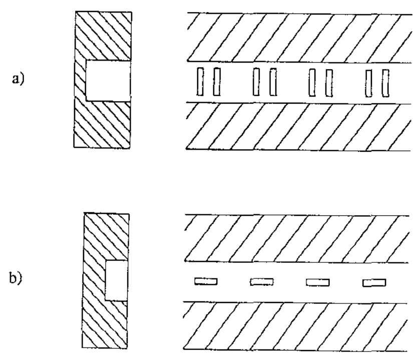


Figure 1: Linear Arrays in I.D.G.; a) vertically, b) horizontally, polarised.

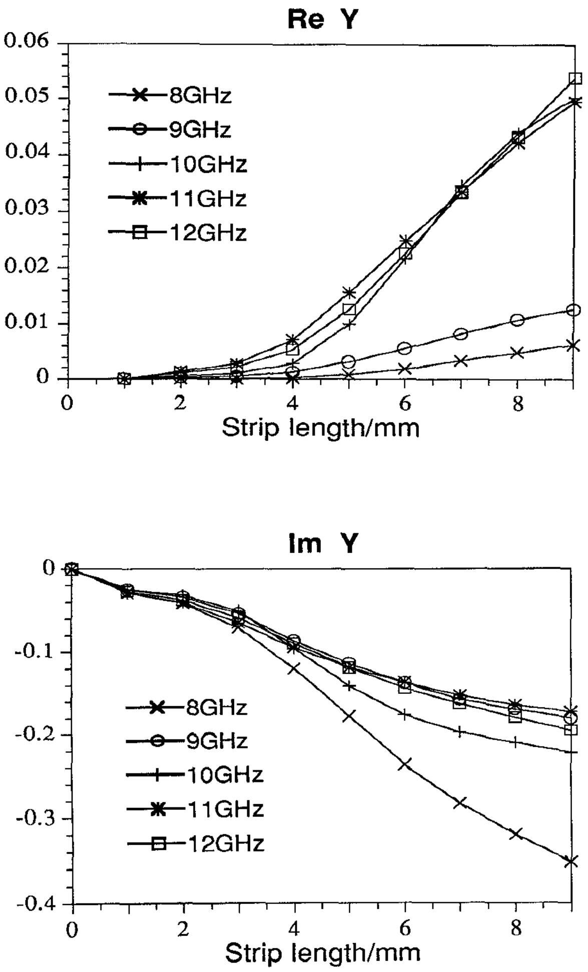


Figure 2: Y-Parameters of the Transverse Strips.

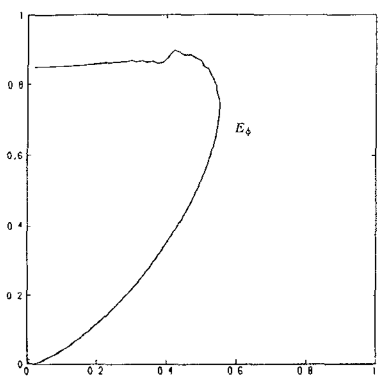


Figure 3a: Far Field Variation in the Long. plane of a 5mm strip @ 10GHz.

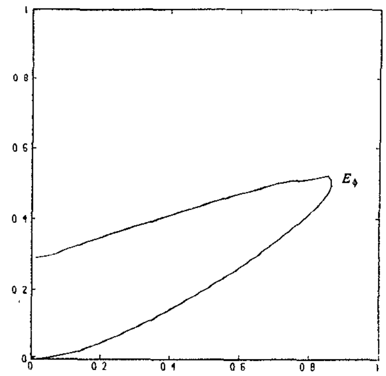


Figure 3b: Far Field Variation in the Long. plane of a 5mm strip @ 12GHz.

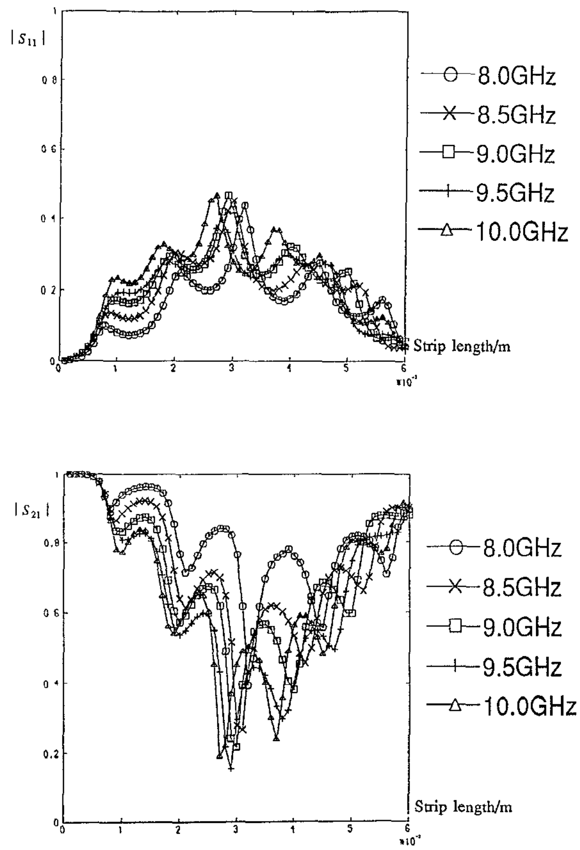


Figure 4: S-Parameters of the Longitudinal Strips, (width=2mm).

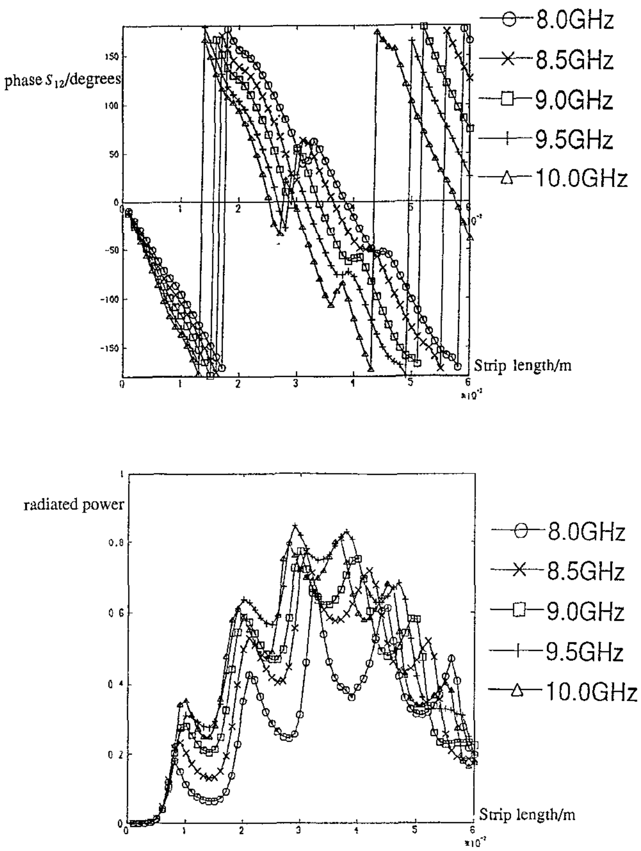
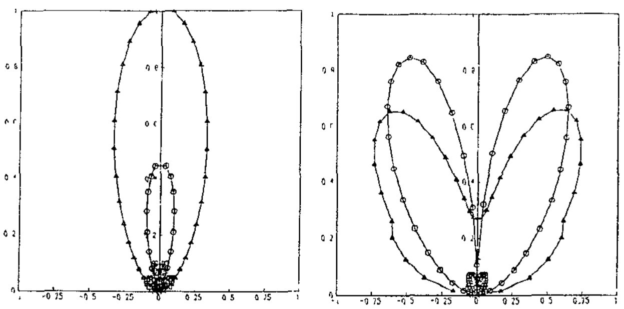


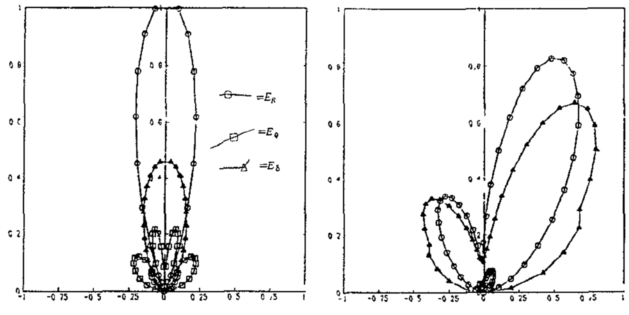
Figure 4: Cont.

Variation in the Trans. plane. **Variation in the Long. plane.**

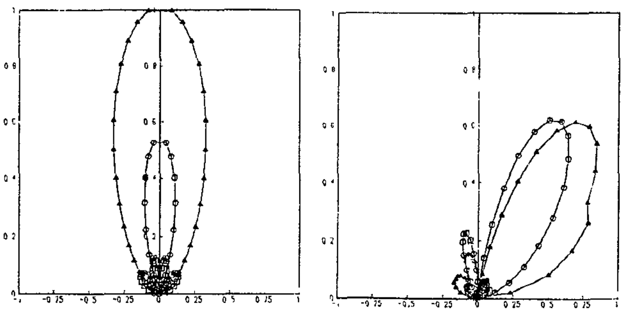


a) Strip length=10mm

Figure 5: Far Field patterns of the Longitudinal Strips @ 10GHz, (width=2mm).



b) Strip length=20mm



c) Strip length=30mm

Figure 5: Cont.

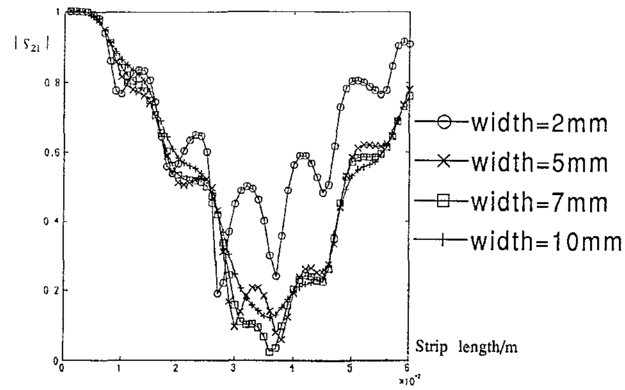


Figure 6: S-Parameter Variation with long. Strip Width.