Letters

Corrections to "Electromagnetic Field Plot of an Inductive Window by the Moment Method"

John R. Natzke, Mark R. Wolski, and Thomas Koryu Ishii

The above paper[1] contains three errors. Equation (5) should read:

$$G_{iy}^{y}(\bar{r}/\bar{r}_i) = \frac{-j}{ab}\sum_{m,n}\left\{\frac{2-\delta_o}{k_c^2 k_z}\left[\left(\frac{m\pi}{a}\right)^2 - \frac{k_z^2}{k^2}\left(\frac{n\pi}{b}\right)^2\right]\right.$$

$$\cdot \sin\frac{m\pi x}{a}\cos\frac{n\pi y}{b}\sin\frac{m\pi x_i}{a}\cos\frac{n\pi y_i}{b}$$

$$\left.\cdot \exp\left(-jk_z|z-z_i|\right)\right\} \quad (5)$$

Equation (6) should read:

$$A_{iy}^{y}(m) = \frac{1}{ab\sqrt{\left(\frac{m\pi}{a}\right)^2 - k^2}} \quad (6)$$

Finally, one line above (12) should read:

from the S matrix as follows [7]:

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[1] J. R. Natzke, M. R. Wolski, and T. K. Ishii, *IEEE Trans. Microwave Theory Tech.*, vol. 39, no. 8, pp. 1296–1300, Aug. 1991.

Comments on "Whispering Gallery Dielectric Resonator Modes for *W*-Band Devices"

M. J. Niman

The above paper[1] is a valuable contribution to a field which has little coverage in the literature. Working through the results however, it is felt that a discrepancy exists which may mislead other workers in this subject. In this regard, Section II-D and Fig. 6 which discuss a measurement in the 75–110 GHz band, raise most concern. In the paper the resonances on the plot (reproduced in Fig. 1) are attributed to whispering gallery (WG) modes $WGE_{6\text{-}10,0,0}$ and $WGH_{6\text{-}10,0,0}$ for an alumina resonator of 5 mm diameter and 0.635 mm high. Verifying this performance with our own analysis software which is based on Wait [1] and Arnaud [2] strongly suggests that in fact a set of higher order radial modes are being measured: $WGE_{6\text{-}10,1,0}$ and $WGH_{6\text{-}10,1,0}$.

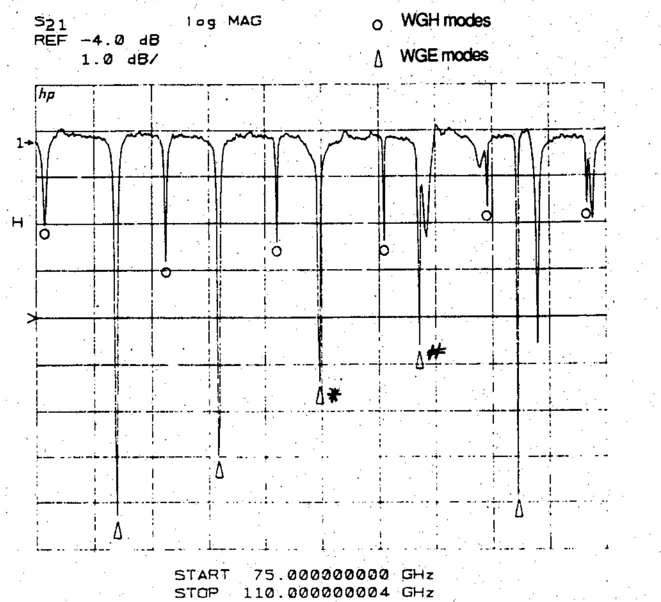

Fig. 1. Measurement of whispering gallery mode resonator (reproduced from Fig. 6 in the Cros and Guillon paper).

TABLE I
COMPARISON BETWEEN PUBLISHED DATA AND THEORETICAL CALCULATIONS

	Current Work (Theoretical)				Published (Measured)	
n	$WGH_{n,0,0}$	$WGE_{n,0,0}$	$WGH_{n,1,0}$	$WGE_{n,1,0}$	$WGH_{n,0,0}$	$WGE_{n,0,0}$
6	52.824	59.324	74.158	80.602	75.46	79.88
7	59.975	66.424	81.910	88.443	82.83	86.05
8	67.022	73.426	89.518	96.079	89.74	92.35
9	73.990	80.358	97.005	103.546	96.28	98.48
10	80.893	87.218	104.392	110.919	102.72	104.57
11	87.740	94.037			108.89	
12	94.550	100.819				
13	101.317	107.546				
14	108.049	114.252				

The results of our own analysis along with the published results are given in Table I. Since it was not stated in the paper, the alumina was assumed to have $\epsilon_r = 9.8$ and the correction factor for resonator thickness has been ignored for simplicity. The WGH modes in particular correlate very well for the higher radial wavenumbers. The agreement for WGE modes is less conclusive, possibly as there are affected more by the above assumptions. Nevertheless it is clear that it cannot be the fundamental $WG_{n,0,0}$ modes that are being measured as stated. An extended analysis also suggests possible explanations for some of the other unidentified peaks in the response. Using the theoretical frequencies the longitudinal electric field may be plotted versus radius [3] which demonstrates

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[1] D. Cros and P. Guillon, *IEEE Trans. Microwave Theory Tech.*, vol. 38, no. 11, pp. 1667–1674, Nov. 1990.

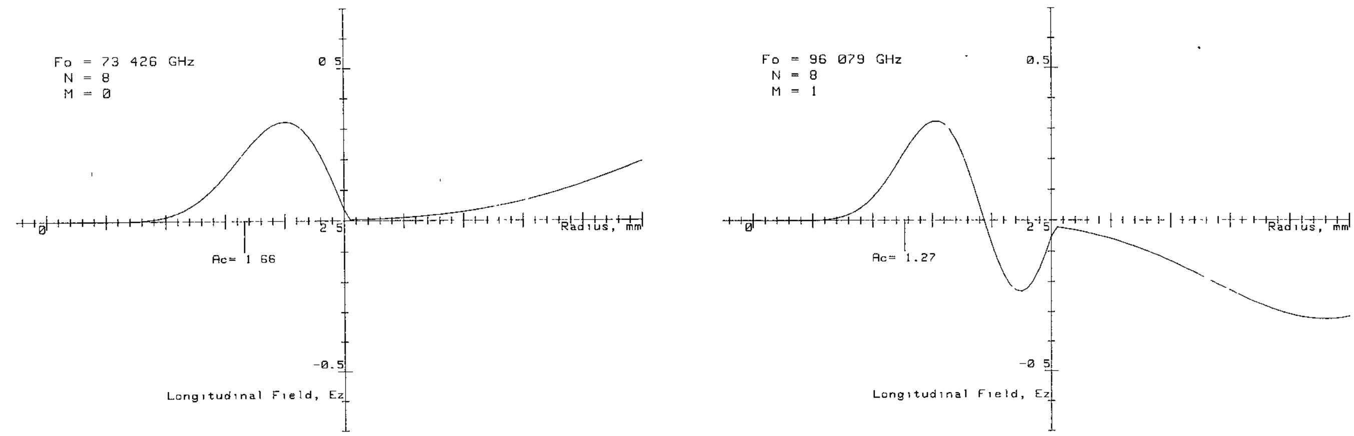

Fig. 2. (a) Longitudinal electric field for mode $WGE_{8,0,0}$ (b) Longitudinal electric field for mode $WGE_{8,1,0}$.

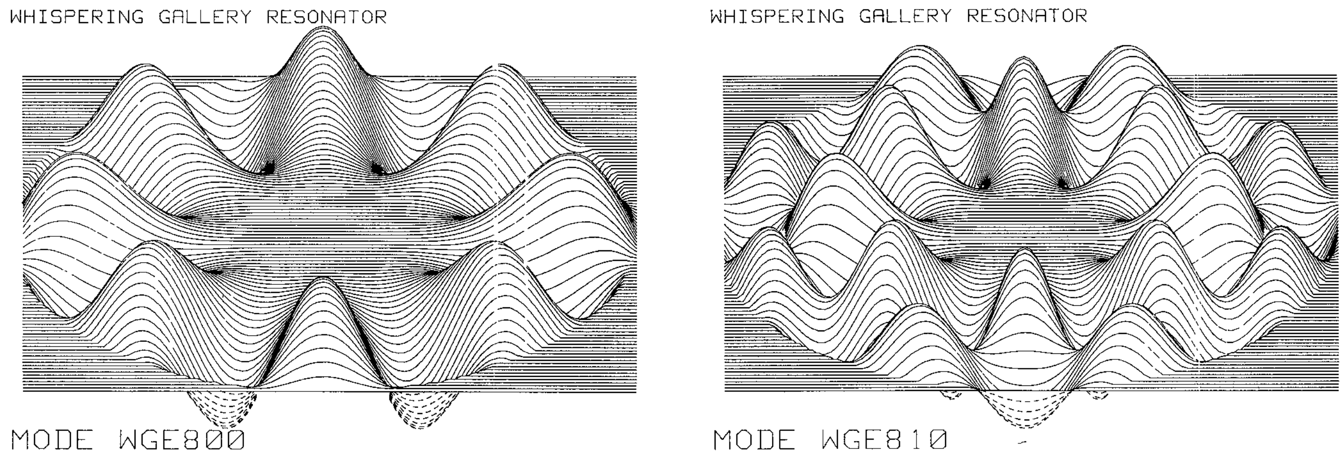

Fig. 3. (a) Electric field amplitude for mode $WGE_{8,0,0}$ (b) Electric field amplitude for mode $WGE_{8,1,0}$.

the difference between the fundamental and first order radial wave numbers. This is shown in cross-section in Fig. 2(a) and (b) for $WGE_{8,0,0}$ and $WGE_{8,1,0}$ respectively, and in 3D in Fig. 3(a), (b). Another possibility is that the azimuthal mode numbers have been incorrectly identified, and that higher modes are responsible—$WGH_{9-14,0,0}$ and $WGE_{9-14,00}$. However this is thought to be less likely.

The author presumes that the waveguide band-limited equipment used to make the measurements (a Hewlett-Packard W-Band 8510 Network Analyzer) did not allow the discovery of the lower frequency fundamental modes. Certainly, more information on this aspect and the actual dielectric constant of the material used would be welcomed. A final comment concerns Fig. 2 in the paper where a pentagram represents a ray-optic approximation for a WG propagation example. This is misleading and should more properly be a pentagon tangential to a somewhat larger caustic radius.

References

[1] J. R., Wait, "Electromagnetic whispering-gallery modes in a dielectric rod," *Radio Sci.*, vol. 14, no. 39, pp. 1005–1017, Sept. 1967.

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[3] P. Guillon, X. H. Jiao, P. Auxemery, and L. A. Bermudez, "Whispering-gallery modes herald DR mm-wave use," *Microwaves and RF*, pp. 85–96, Sept. 1987.

Authors' Reply[2]

Dominique Cros and Pierre Guillon

For the calculation of the electromagnetic parameters of the resonator excited on whispering gallery modes (WGM's), we use the finite element method. This numerical analysis permits the calculation of the resonance frequency, the unloaded Q factor and also to draw the field cartography associated with each modes. With this

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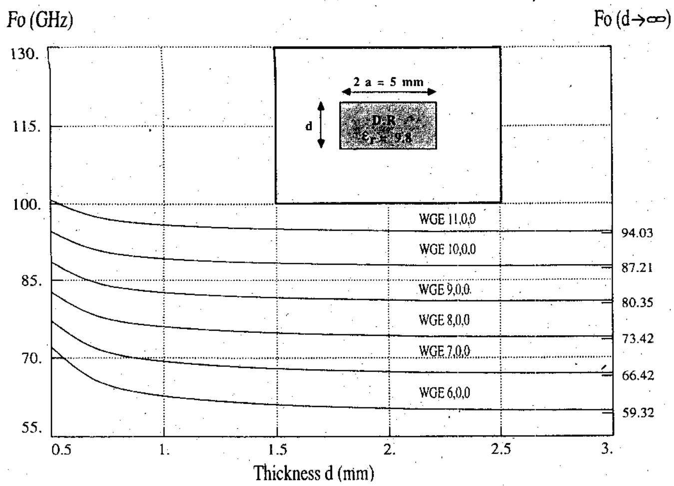

Fig. 1. Resonance frequency variations as a function of the resonator thickness for the WGE modes.

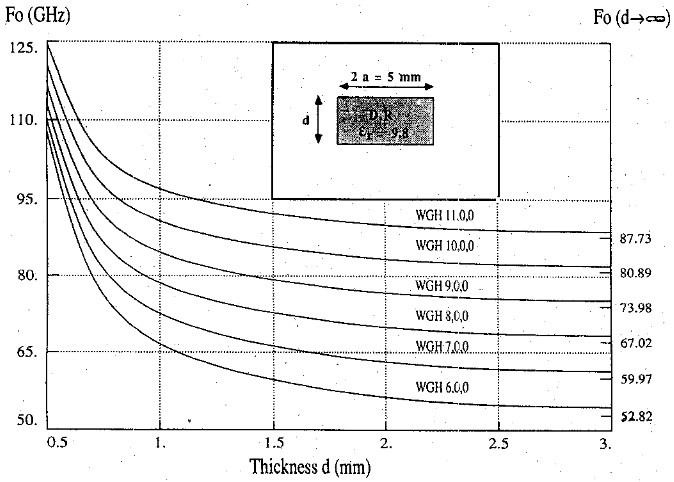

Fig. 2. Resonance frequency variations as a function of the resonator thickness for the WGH modes.

method, it's possible to take into account the exact resonator geometry (diameter and thickness) and that of its environment (substrate parameters).

The whispering gallery modes are described as comprising waves running against the concave side of the cylindrical boundary so the diameter of the resonator is an important parameter for resonance frequency calculation.

For large thickness (which corresponds in Mr. Niman's comments on our paper to the case of a dielectric rod), the axial wave variation can be neglected. Then the resonance frequencies depend essentially of the diameter of the resonator. But this property is not true when the thickness of the dielectric resonator is small. In this case the resonance frequencies of WGM's increase when the thickness decreases.

With the finite element method we have calculated the resonance frequencies of a resonator made in alumina ($\epsilon_r = 9.8$) corresponding to that used in our paper.

The resonator diameter is equal to 5 mm and the thickness is moving between 0.5 mm to 3 mm.

If we consider the resonator alone (without substrate), the results are given in Fig. 1 for WGE modes and in Fig. 2 for WGH modes.

On the right of these figures (1 and 2), the results have been compared with the resonance frequencies for the cylindrical rod given in Mr. Niman's comments on our paper.

TABLE I
THEORETICAL AND EXPERIMENTAL RESULTS COMPARISON

	Resonant Frequencies Measured (GHz) (HP *W* band 8510)		Resonant Frequencies Calculated (GHz) (Finite Element Method)	
n	$WGH_{n,0,0}$	$WGE_{n,0,0}$	$WGH_{n,0,0}$	$WGE_{n,0,0}$
6	75.46	79.88	74.43	79.60
7	82.83	86.05	82.02	85.91
8	89.74	92.35	89.20	92.24
9	96.28	98.48	96.03	98.59
10	102.72	104.57	102.66	104.90
11	108.89		109.15	

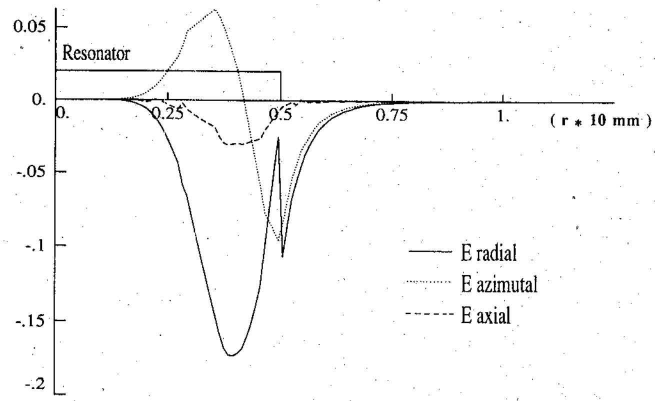

Fig. 3. Variation of the three electrical field components in the radial direction for the $WGE_{10,0,0}$ mode.

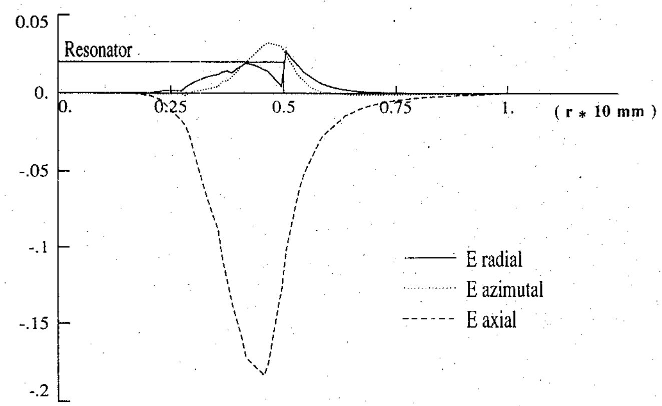

Fig. 4. Variation of the three electrical field components in the radial direction for the $WGH_{10,0,0}$ mode.

The finite element method results has been compared with the experimental one's. In this part the dielectric resonator (diameter 5 mm, thickness 0.635 mm) made from alumina ($\epsilon_r = 9.8$) is placed on a substrate ($\epsilon_r = 3.2$) of thickness 0.127 mm near a microstrip line. The measurement was realised in the 75–110 GHz band using a Hewlett-Packard W-band 8510 Network Analyzer. The comparison of theoretical results obtained by means of the finite element method and the experimental one's given in our paper, Fig. 6 is given in Table I. Using the same theoretical analysis we have drawn the variation of the three electrical field components for both $WGE_{10,0,0}$ and $WGH_{10,0,0}$ mode, respectively on Figs. 3 and 4.

Finally, we give on Figs. 5 and 6 for WGE and WGH modes, respectively, the variations of the resonance frequency of the dielectric resonator ($\epsilon_r = 9.8$, diameter 5 mm) as a function of its

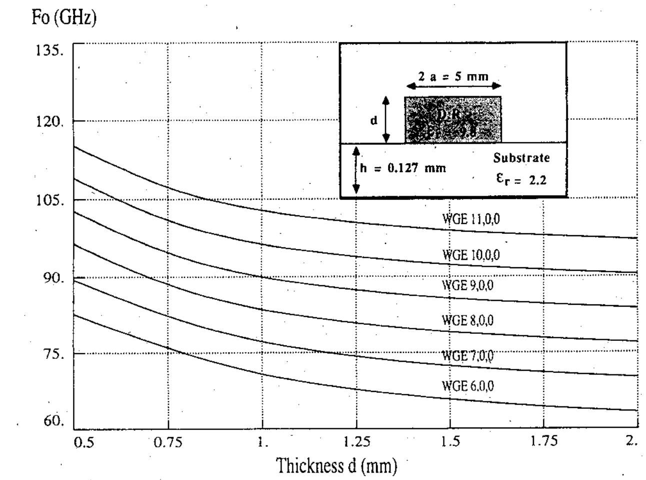

Fig. 5. Resonance frequency variations as a function of the resonator thickness for the WGE modes.

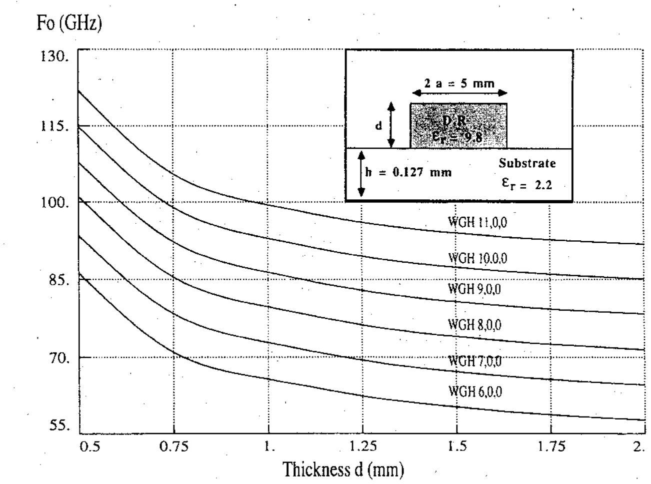

Fig. 6. Resonance frequency variations as a function of the resonator thickness for the WGH modes.

thickness. In this case, the resonator is placed on the same dielectric substrate as previously ($h = 0.127$ mm, $\epsilon_r = 2.2$).

These results confirm that the resonance frequency of WG modes depends on the thickness of the resonator in particular when this one is not too large.

Comments on "A Novel Method for Modeling Coupling Between Several Microstrip Lines in MIC'S and MMIC'S"

Eugenio Costamagna

In the above paper[1], the capabilities of a described four-port generalized coupling model (GCM) in analysing multiple coupled microstrip line circuits are deeply explored. The model is used to describe coupling between nonadjacent lines as well as adjacent ones, and interesting results are shown.

A rather similar method for modeling couplings in multiple line structures was described in [1], based on a different algorithm to compute line self-admittences in an indefinite admittance matrix scheme [2] for the overall circuit analysis. This method utilizes the equivalent circuit for asymmetric coupled pairs of lines in inhomogeneous dielectric described in [3], which generalizes the Zysman and Johnson's model for symmetric pairs [4], and completes the description in terms of decoupled transmission lines and congruence transformers and the time domain analysis of Chang [5]. The circuit parameters can be easily shown to be consistent with the full modal analysis provided by Tripathi [6], [7]; special cases have been examined by Speciale [8] and by Allen [9].

Routines based on this equivalent circuit and on the Zysman and Johnson's one have been implemented at Marconi Italiana in general purpose programs (see the short descriptions of the MARE and MIDFO programs in [10]), to perform accurate analysis and synthesis of microstrip and suspended substrate line devices in quasi-TEM wave propagation.

Although possible in principle, as shown by Swanson, we have not utilized these routines to describe couplings between nonadjacent lines, because their primary use concerned shielded structures, where nonadjacent lines were very weakly coupled. The interesting results now obtained by Swanson in applying the GCM to non adjacent lines encourage me to draw the reader's attention to a further type of model improvement, also described in [1], which introduces a building block concept in modeling multiple coupled line structures. In fact, segmenting the coupled lines as described in [1] allows to more precisely modeling, by the equivalent circuit in [3] or a similar four-port, the local coupling among various lines. Some results are given in [1], where the dramatic improvement in the analysis results which arises in some cases is illustrated by considering a three line microstrip circuit, for which exact reference parameter values can be provided from the Tripathi's [11] analytical description.

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IEEE Log Number 9107028.
[1] D. G. Swanson, Jr., *IEEE Trans. Microwave Theory Tech.*, vol. 39, no. 6, pp. 917–923, June 1991.

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[2] M. A. Murray-Lasso, "Analysis of linear integrated circuits by digital computer using black-box techniques," in *Computer Aided Integrated Circuit Design*, G. E. Herskowitz, Ed. New York: McGraw-Hill, 1968, ch. 4.
[3] E. Costamagna and U. Maltese, "Linee accoppiate asimmetriche in dielettrico non omogeneo," *Alta Frequenza*, vol. XL, N. 9, pp. 737–741, Sept. 1971 (in Italian).
[4] G. I. Zysman and A. K. Johnson, "Coupled transmission line networks in an inhomogeneous dielectric medium," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-17, pp. 753–759, Oct. 1969.
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