Integration of NRD Guide and Slot Line for Millimeter Wave Indoor Wireless Applications

Nagendra P. Pathak

Abstract— This paper reports the integration technique for the integration of Non-Radiative Dielectric guide and Slot line at millimeter wave frequency. HFSS is used to obtain dispersion characteristics of integrated NRD Guide - Slot line structure. This structure supports slot line mode which have no cutoff and Quasi LSM mode having cutoff frequency 42 GHz. The next higher order mode get excited after 67 GHz which is much above the range of interest (57 GHz - 66 GHz). A tapered transition is designed to launch power from dominant LSM_{11} mode of NRD Guide to Slot line for the frequency range 58 GHz – 64 GHz. The return loss of designed transition is less than 20 dB for entire range of interest.

***Index Terms*—Non Radiative Dielectric wave Guides, Slot lines, Millimeter wave Integrated Circuits, Transition.**

I. INTRODUCTION

The millimeter-wave region of the electromagnetic spectrum, which typically spans from 30 to 300 GHz, represents a vast spectrum resource with enormous potential applications. Due to smaller wavelengths, greater bandwidth and more interaction with atmospheric constituents, millimeter-wave region is useful in applications requiring high-speed data transmission, broadband cellular communications, secure communications, and variety of radar systems. The millimeter wave systems used in the above applications are made of many electronic parts called 'circuits' or 'components'. The technology for the development of these electronic circuits in the microwave frequency range is well developed. Considerable research work is currently being carried out to improve technology for the development of these components in the millimeter-wave frequency region. The main emphasis is to make the components more compact, and cost effective. Non Radiative Dielectric Wave Guide is prominent transmission media that can be used to develop high performance and low cost systems at millimeter wave frequencies [1, 2 and 3]. Integration of NRD Guide with Microstrip line, Suspended strip line are discussed in [2, 3]. This paper reports the integration mechanism of NRD guide and Slot line. Theory of NRD Guide and Slot line are described in section II and the dispersion characteristics of the integrated NRD-Slot line is described in section III. Characteristics of designed tapered transitions are given in section IV and finally conclusions are described in section V.

Authors are with the Indian Institute of Technology, Roorkee, Uttarakhand, Pin-247667 (India)
Phone-+911332285771, Email- nagppfec@iitr.ernet.in

II. THEORY

A. *NRD GUIDE:*

Non Radiative Dielectric wave guide consists of a rectangular dielectric strip, of cross-section $a \times b$ and relative dielectric constant ε_r, which is sandwiched between two parallel metal ground plates (Fig.1). The plate separation a is less than half the free-space wavelength ($\lambda_0/2$) so that fields are cut off in the air region. The presence of dielectric strip enables electromagnetic waves to propagate along the strip, whereas, radiated waves due to discontinuities in the structure are suppressed because of the cutoff nature of surrounding air-filled region. The incident field should exhibit symmetry giving a *PMC*. midway between the metal plates. This wave-guide structure supports two modes that are non-radiative (Fig. 2). The first non-radiative mode is LSE_{11} mode and the second non-radiative mode is LSM_{11} mode. Since the E-field lines for the LSE_{11} mode are mainly perpendicular to the NRD guide ground planes, it is a lossy parasitic mode and is undesirable. The E-field lines for

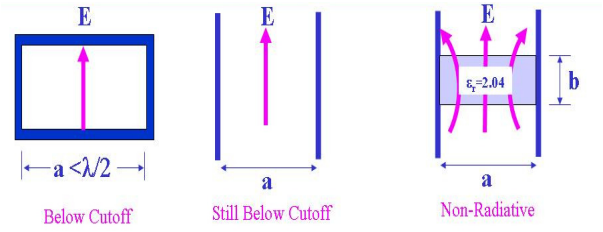

Fig. 1 Concept of NRD Guide

LSM_{11} mode are mainly parallel to the ground metal plates; hence it is a low loss mode used in the design of NRD guide circuits. The NRD guide excited in the low loss LSM_{11} mode serves as the basic building block for developing various transceiver circuit elements at millimeter wave frequencies. In certain cases, a mode suppresser is used to suppress the undesired LSE_{11} mode. The NRD guide structure also supports several parallel-plate types of modes, with E-field lines originating from one plate and terminating on the other. To avoid these modes, NRD guide components are usually

made symmetrical about the plane parallel to and midway between the ground planes. If the feed (usually rectangular wave guide) also conforms to this symmetry (the symmetry plane effectively becomes a perfect magnetic conductor '*PMC*'), then only the LSE_{11} and LSM_{11} modes can propagate.

B. SLOT LINE:

Slot line structure consists of a dielectric substrate metallized on one side only. The metallization has a completely separating narrow slot etched into it to form the slot line. A hybrid mode of the quasi TE type propagates along the slot. This structure can not support Quasi TEM mode of other strip transmission lines. Slot line mode has no cutoff frequency and the main energy concentration is in the slot, or close to it. The electric field lines for slot line mode are shown in Fig. 3.

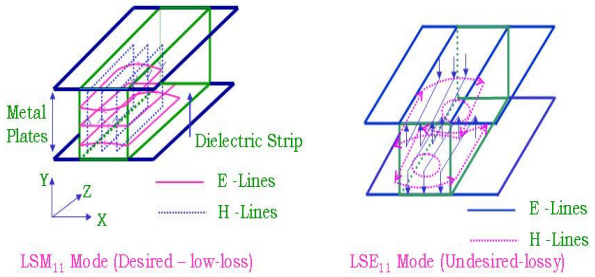

Fig.2. Propagating modes in NRD Guide

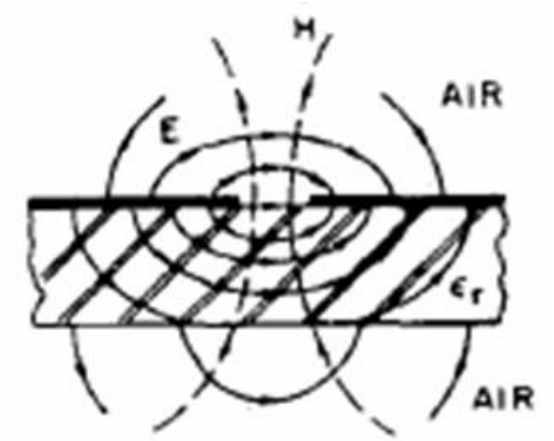

Fig. 3 Field Lines for Slot line mode

C. INTEGRATION MECHANISM:

If we place slot line at the centre of NRD guide (Fig.4), it is possible that E-field lines of slot line mode and LSM_{11} mode of NRD guide becomes parallel to each other. Therefore, it is possible to integrate two transmission line structures that can be used for the design of low cost millimeter wave components used in the wireless applications.

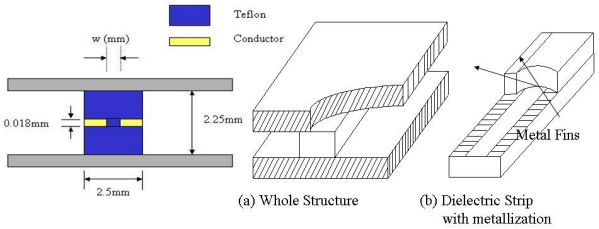

Fig. 4 Integration of NRD Guide and Slot Line

III. DISPERSION CHARACTERISTICS

Dispersion characteristics of integrated NRD-Slot line are shown in Fig. 5. It is clear from the dispersion characteristics of this wave guide that up to 68 GHz frequency, only two modes are propagating viz. slot line mode which have no cutoff frequency and quasi LSM mode which have cutoff frequency 42 GHz. Next higher order mode get excited at 68 GHz. It has been observed that LSM_{11} mode of NRD guide get converted into slot line mode in slot region and carried out most of the power. Variation of guide wavelength and characteristic impedance with slot width are shown in Fig. 6.

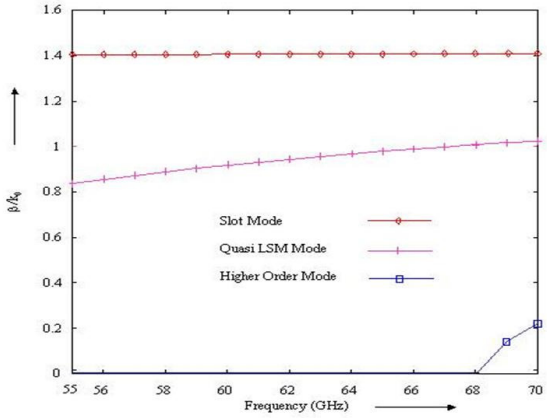

Fig. 5 Dispersion Characteristics of NRD Guide

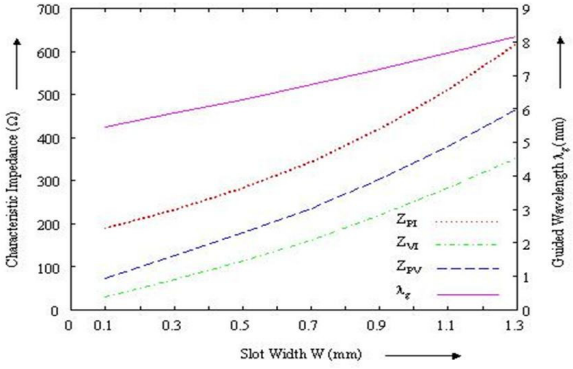

Fig. 6 Variation of Guide wavelength and Characteristic Impedance with slot width

IV. DESIGNING OF TAPERED TRANSITION

A tapered transition [4, 5] from NRD guide to NRD-Slot line structure is designed as shown in Fig. 7. Variation of reflection coefficient for different types of taper is shown in Fig. 8. It is clear from the Fig. 7 that although exponential taper response is quite good, but we can use linear taper with reflection coefficient less than 20 dB from frequency range 58 GHz-64 GHz.

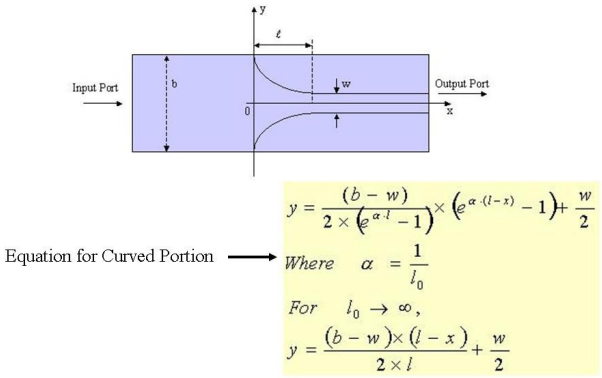

Fig. 7 Transition from NRD Guide to Integrated NRD-Slot Line

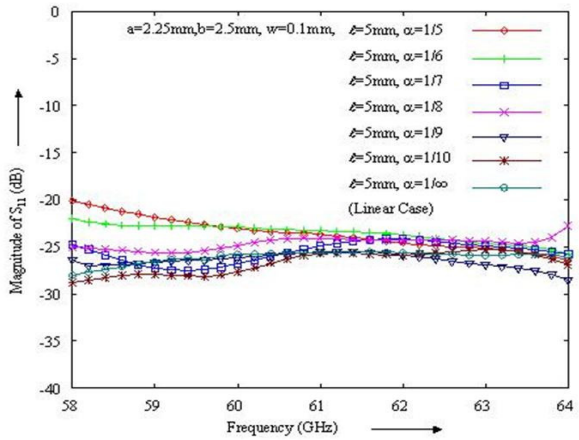

Fig. 8 Characteristics of NRD Guide to NRD-Slot line Transition

V. CONCLUSION

An integration mechanism for integrating NRD Guide and slot line is presented. This integrated structure can be used to develop high performance and low cost systems at 60 GHz frequency.

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