# Non-leaky Coplanar Waveguide Active Antenna

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## Abstract

A newly developed structure, non-leaky coplanar waveguide (NLC) , is used for an active antenna. Spectral domain and FDTD codes are developed to provide the design parameters. The circuit is successfully operated with an antenna gain better than the CPW design.

## 1 Introduction

The conductor-backed coplanar waveguide (CBCPW) [1] and slot line (CBSL) are used in the MMIC due to several advantages, such as improved mechanical strength and heat sinking ability compared to CPW. However, the presence of conductor backing causes an energy leakage [2] [3] which deteriorates the CBCPW circuit performance. To eliminate this leakage, we developed a non-leaky coplanar (NLC) waveguide in which one additional layer with a lower dielectric constant is inserted between the original substrate and the metal ground plane as in Fig.1 [4] [5]. This paper describes an NLC based active antenna for demonstration of the usefulness of NLC at 20 GHz. A GaAs HEMT is used as an active source whereas a slot antenna made on an NLC substrate is used as a radiating element and a load for the oscillator. In the design, a spectral domain analysis (SDA) and a finite difference time domain (FDTD) techniques are utilized to provide the NLC circuit design parameters.

## 2 Circuit Design and Performance

### 2.1 *NLC-fed Slot Antenna Design*

Before designing the circuit, we need to decide the appropriate substrate thickness of two different layers. It is important to make sure that the structure is non-leaky both in coplanar waveguide and slotline region [6]. Fig.1 shows that there is no leakage for the chosen structure in the frequency range of interest. Once the NLC structure is determined, the analysis of the slot antenna is followed.

For the accurate active antenna design, precise knowledge of the input impedance of the slot antenna is essential. The SDA and FDTD codes are developed to calculate the input impedance of the NLC-fed slot antenna. The results agree well with each other indicating the accuracy of the two different methods.

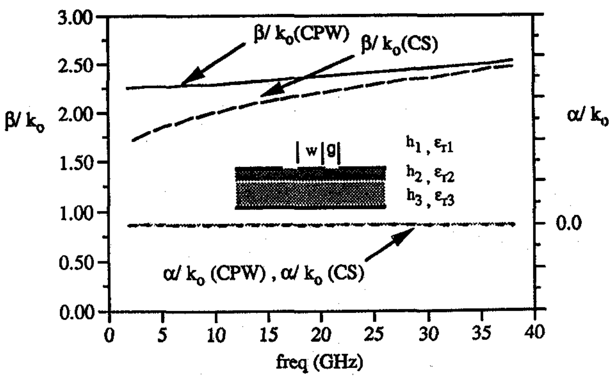


Fig 1. NLC structure and Normalized phase and attenuation constant vs. frequency ($\epsilon_{r1} = 1$, $\epsilon_{r2} = 10.8$, $\epsilon_{r3} = 2.2$, $h_1 = 30.0mm$, $h_2 = 0.635mm$, $h_3 = 3.175mm$, $w = 0.813mm$, $g = 0.406mm$)

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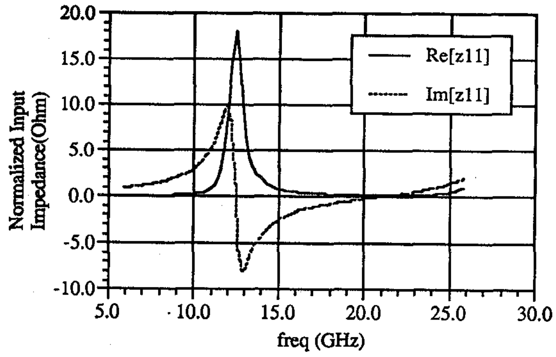


**Fig 2. Input Impedance of NLC feed slot Antenna**

In the design, the SDA code was used first to find the slot dimension which resonates at 20 GHz. The dimension of $1\lambda$ slot antenna is $240mil(= 6.096mm) \times 24mil(0.610mm)$ and the input impedance is $13.2 - j4.1$. Then the FDTD code was applied to simulate the circuit performance. The input impedance of the slot antenna as a function of frequency was evaluated by FDTD based on the above dimension determined by SDA code. The results are shown in Fig.2. The values are normalized by the characteristic impedance of the NLC feed line.

## 2.2 *NLC Active antenna design and Measurements*

The NLC active antenna was designed based on the input impedance of the NLC slot antenna as mentioned above. The substrate is a $5cm \times 5cm$ section consisting of $0.635mm$ thick Duroid 6010 which has a dielectric constant $\epsilon_r = 10.8$ and $3.175mm$ thick Duroid 5870 which has $\epsilon_r = 2.2$. The circuit layout of the one element active antenna with NLC structure is shown in Fig.3. A GaAs HEMT (Mitsubish MGF-4310) was used as the source. For the bias design, narrow slits in the ground plane were created to separate drain and gate bias. To reduce the field discontinuity on the slit, the slit positions were determined where they have high impedance. For RF short, capacitive pads were used.

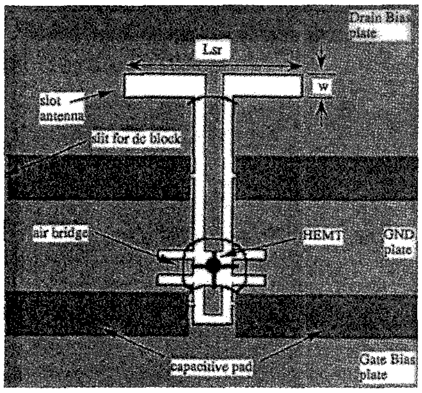


**Fig 3. The circuit layout of the active antenna**

As shown in Fig.4, the measurement indicates an oscillation at 19.82 GHz with the bias condition ($I_{ds} = 10mA$, $V_{ds} = 2.01V$, and $V_{gs} = -0.43V$). This signal was slightly shifted as compared to the oscillation frequency (20.2 GHz) of the corresponding CPW active antenna. The EIRP was 5.2 dBm and isotropic conversion efficiency was 16.6%. This results are comparable to the CPW active antenna using the same device. However, the gain of the NLC antenna was improved by 1.7 dB mainly due to unidirectional nature of the NLC structure which is another advantage of NLC compared to CPW structure. The measured radiation pattern is shown in Fig.5.

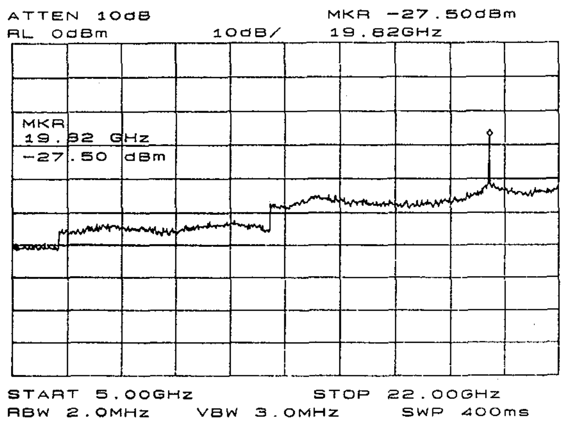


**Fig 4. Measured Power Spectrum**

## 3 Conclusion

An active antenna with a one-element slot was designed in an NLC structure. The design is based on electromagnetic calculation of the input impedance of an NLC slot antenna. The antenna gain was improved over the similar active antenna based on the CPW structure. No leakage was detected which would be observed in the circuit using a conventional conductor backed CPW.

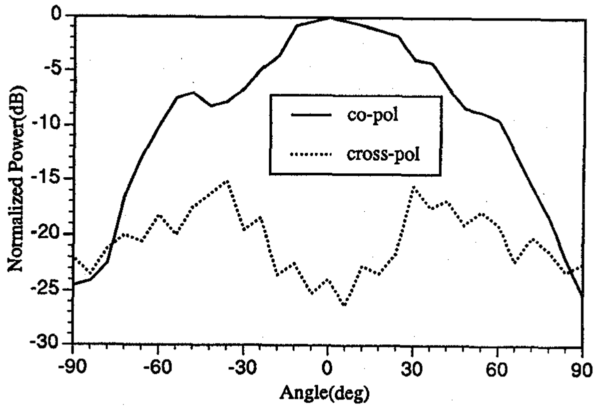


Fig 5. Measured Antenna Pattern


## Acknowledgment

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