A K-band Biconical Antennas System for Wireless Wideband Communication Equipments

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Abstract—In this paper a biconical antennas system operating in a wideband TX/RX video and voice communications module is described. The antenna module is part of a K-band (38.3-38.6 GHz) equipment installed in a vehicle on the move composed by two different units: the IDU, indoor unit, is installed inside the vehicle and the ODU, outdoor unit, is installed on the top of the vehicle. The ODU is composed by the RF transceiver and the antennas system that is formed by two equal biconical antennas performing the transmitting (TX) and receiving (RX) functionality respectively. The fabricated antennas, characterized by reduced size and low weight, are fed through WR28 rectangular waveguide obtaining minimum insertion loss in connecting the antennas itself with the system.

Keywords — Broad Band Antennas, biconical antennas, wideband communication systems.

I. INTRODUCTION

The fast growing demand for microwave communication technologies, such as broadband wireless and space communication, point to point radio link, and a large variety of on the move network for data and voice exchange, is bringing up stringent requirements for high performance systems. In fact, the most critical requirements when treating with wireless communications equipment are range and power consumption being these two aspects interrelated. In these circumstances, enhanced performances are needed by the whole system and consequently there is a continuing demand for broader bandwidth and strict radiation pattern antennas, with reduced size and weight.

When the operational condition requires an omnidirectional link, the biconical one is an easy way to build up broad-band antennas with omnidirectional radiation pattern but, as the operation frequency increases, there is the need to avoid the classical coaxial feed in order to reduce the power loss between the antenna and the TX/RX circuit blocks.

In this paper a K-band biconical antenna is described. It is part of a system composed by two different units called ODU and IDU respectively and implements two equal antennas, fed through WR28 rectangular waveguide, performing respectively the TX and RX functionality.

II. SYSTEM OVERVIEW

In fig.1 the block diagram of the whole system is shown. The ODU block diagram is shown in fig.2. The TX and RX chains of the ODU are connected with two different antennas avoiding any kind of switch. This is necessary when high sensitivity and long range are required from the transceiver. In fact, as the frequency increases up to about forty GHz, it is very difficult to realize signal switch with low insertion loss and high power handling, and consequently obtaining low system’s noise figure. In fig.3 a view of the ODU is presented. As shown the two antennas are placed in different height positions in the way to achieve the best decoupling.
As mentioned, when specifications require an omnidirectional link the biconical one is an easy way to build up a broadband antennas with uniform horizontal radiation pattern [1-4]. Moreover the biconical antenna allows an extremely flexible design of its characteristics at low cost. The biconical antenna consists of two opposite conical horns as shown in fig.4.

In traditional analysis of biconical antenna, only the dominant mode is excited. The dominant or fundamental mode of the biconical structure is the transverse ElectroMagnetic (TEM) mode which is the solution of Maxwell's equations (with biconical boundary conditions) and provides a field perpendicular to the radial direction. As mentioned a coaxial waveguide is typically used to excite the antenna with the TEM mode but, for our purpose (38.3-38.6 GHz operating frequency range), we choose a WR28 rectangular waveguide, realizing a rectangular to circular transducer [5-6], in order to reduce the guide insertion loss.

In fig.5 a front and bottom view of the designed structure are presented.

The biconical antenna problem has been solved on a finite difference time domain grid in a cylindrical coordinate using Matlab [7-8]. Starting from the following expressions obtained by applying rotor operator to Maxwell equations in spherical coordinates:

\[
\begin{align*}
(V \times E) &= \frac{1}{r \sin \theta} \left[ \frac{\partial}{\partial \varphi} (E_\varphi \sin \theta) - \frac{\partial}{\partial \varphi} (E_\theta \sin \varphi) \right] = j \omega \mu_0 H_y,

(V \times E)_\theta &= \frac{1}{r \sin \theta} \left[ \frac{\partial}{\partial \varphi} (E_\varphi \sin \theta) - \frac{\partial}{\partial \varphi} (E_\theta \sin \varphi) \right] = j \omega \mu_0 H_\theta,

(V \times E)_r &= \frac{1}{r \sin \theta} \left[ \frac{\partial}{\partial \varphi} (r E_\varphi) - \frac{\partial}{\partial \varphi} (r E_\theta) \right] = j \omega \mu_0 H_r
\end{align*}
\]

(1)

due to the symmetry of the structure we have:

\[
\begin{align*}
H_y &= \frac{E_\theta}{\sin \theta} e^{-j \beta r} \\
E_\theta &= \eta_0 H_y = \frac{H_y}{\sin \theta} e^{-j \beta r}
\end{align*}
\]

(2)

Of course, the structure shown in fig.4, with infinite cones dimension, is only an ideal one but non-idealities can be easily taken into account during the analysis. In particular great attention has been paid in considering corrective additional terms due to the insertion of the low dielectric constant material inserted between the cones in the way to support and insulate the antenna (and so the whole system) from the external environmental conditions.

**Results:**

In fig. 6, the photo of one antenna is shown. Fig. 7 shows the measured $S_{11}$, whereas in fig. 8 and fig. 9 the test bench of the measurements, carried out for the vertical and horizontal radiation pattern performed in anechoic chamber, is shown.
Fig. 10 and fig. 11 show the measurement results for the vertical and horizontal radiation pattern respectively.

IV. REALIZED ANTENNAS SYSTEM

As mentioned, the TX and RX antennas have been placed in different highness in order to achieve the best decoupling. The RX antenna is the lower one (see fig. 3) in order to reduce the insertion loss between the antenna itself and the low noise amplifier placed inside the ODU. Higher antenna’s (TX antenna) performance are lightly modified by the RX antenna presence; its vertical and horizontal radiation pattern are almost unmodified concerning fig. 10 and fig. 11 results. As far as the RX antenna is concerned, it obviously suffers from a reduction of the radiated pattern gain in the direction of the higher one due to the presence of the waveguide that simultaneously feeds and supports the TX antenna itself. In fig. 12 the test bench for the
measurement of the horizontal radiation pattern of the two antennas placed on the ODU box is shown, whereas fig. 13 shows the new horizontal radiation pattern for the RX antenna.

![Test bench for the horizontal radiation pattern of antennas](image)

![Measured horizontal radiation pattern for the RX antenna](image)

**V. CONCLUSION**

In this paper, a biconical antennas system operating in a wideband TX/RX video and voice communications module has been presented. It is composed by two equal biconical antennas, operating in the 38.3-38.6 GHz frequency range, feeded through WR28 rectangular waveguide, performing respectively the TX and RX functionality. Measurement results, carried out in an anechoic chamber, have proven the excellent performance of the single antenna and the complete system.

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**REFERENCES**