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BROADBAND WIRELESS SYSTEMS AND COMPONENTS – AN OVERVIEW

This paper is dedicated to Prof. Ilija Stojanović on the occasion of his 75^{th} birthday and the 50^{th} anniversary of his scientific work

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and Vladan Stanković**

Abstract. In this paper we describe a review of the now fast growing commercial applications of micro and mm-wave wireless technology. The emerging Microwave Video Distribution System/Local Multipoint Distribution System is predicted to be worth \$billions in the next five to ten years, however no single technology or standard will be capable of satisfying all the MVDS/LMDS market applications. This paper also reviews the micro and mm-wave technologies used in the manufacture of broadband wireless systems.

1. Background

Wireles cable technology has evolved from two similar television distribution services that were created during the 1960s in North America. In that decade, both Canada and United States established an Instructional Television Fixed Service (ITFS) using the 2500 to 2686 MHz band. In the United States the original ITFS rules were established by the federal Communication Commission (FCC) in 1963, alocating a 31 channel (NTSC) spectrum range from 2500 to 2690 MHz. Twenty eight of the thirty one channels were assigned to ITFS service.

Multipoint Video Distribution Service (MVDS) is part of Fixed Service (FS) because it main function is to distribute package of TV signals

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from a given transmitting point to multipoint, to the receivers that could be installed in the houses or at the input of different headends if necessary. MVDS could be realized in different part of FS spectrum. Recently large number of experiments are under road in United States, Canada and Europe in frequency bands 2.5 GHz, 3.6 GHz, 28 GHz and 42 GHz. In USA a few experiments are ongoing in frequency band 2.5 GHz using digital modulation and MPEG-1 with eighth to ten programs in 6 MHz bandwidth, and with four programs using MPEG-2. The upper frequency band is under estimation. Federal Communication Service (FCC) is looking for the use of frequency band 28 GHz for Local Multipoint Distribution Service (LMDS) for which 1 GHz is allocated in two segments 850 and 150 MHz. The system is basically devoted for rural but be installed in suburban in part of urban area using cellular microwave network and lower power transmitters. In Canada two digital MMDS system are operating in the 2.5 GHz band using digital compression technology MPEG-2 and utilizing cellular network. Millimetric Multipoint Video Distribution System (MVDS) was first proposed in Europe by British Telecom, who envisaged a one-way broadcast system satellite and cable distribution. The UK Radiocommunications Agency selected the 40.5 to 42.5 GHz band for MVDS in 1989.

The concept of LMDS (see Figure 1) is essentially cellular and provides a four frequency set: two frequency blocks together with vertical and horizontal polarisation which can deliver 32 channels per household. MVDS systems currently in service are based on analogue FM unidirectional transmission but it is recognised that they must in future be able to offer MPEG2 compatible transmission for entertainment channels. It will also be necessary to provide a return path with a sufficient data rate to allow for interactivity and telephony. In France the frequency band 2.5 GHz is occupied for primary user and 3.6-3.8 GHz for digital MMDS. Switzerland is doing the experiment in Alps using 40GHz technology.

Despite the technological challengers, many aspects of the system fall into the category of consumer electronics where cost will strongly influence the uptake of the system. Apparatus at the consumer site provides the greatest opportunity for high volume, low cost manufacture. The installation of BWS does not require the expense of laying cables, while the higher cost of receivers will be offset by the lower cost of small antennas and their installation, compared with direct broadcast satellite (DBS) systems. The antenna and consumer down converter are packaged in the small (outdoor) unit. The antenna is 10cm (for 40 GHz system) diameter zoned lens antenna associated with a waveguide corrugated feedhorn, with small box for down/up converter. Waveguide E-plane technology is the main filter technology for BWS above 10 GHz.

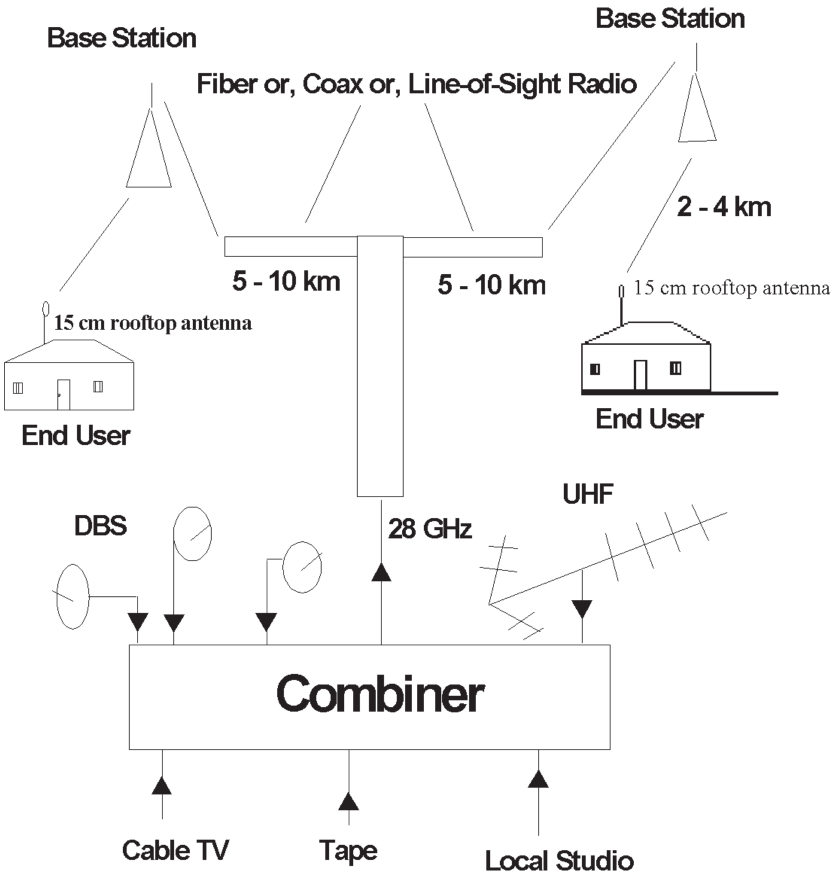

Figure 1. Schematic diagram illustrating the concept of the Local Multipoint Distribution Service (LMDS).

2. Why Broadband Wireless Systems

According to UK telecommunications analysis, broadband wireless is seen as a serious alternative to wired cable or satellite delivery of TV signals in situation where one or more of the following factors prevail:

a) geographical constraints render traditional cable difficult or expensive to install.

b) there are non-existing or inadequate cable infrastructure

c) political factors inhibit the exploitation of satellite services

d) cost is an overriding factor

e) speeds of installation

f) reliability and bit error rate

g) cost and avalability of wired broadband telecommunications

Comparison of broadband wireless systems is given in Table 1.

Table 1. Comparison of Broadband Wireless Systems.

Acronym	**System**	**Frequency**	**Description**
MVDS	Microwave Video Distribution System	40.50–42.50 GHz (12GHz)	One-way or two way analogue or dig. FM/QPSK systems under going trials in Western Europe, East Europe. 12GHz one-way system already fully Operational in Hong Kong.
LMDS	Local Multipoint Distribution Communication System	28–29 GHz (23GHz)	One-way or two way analogue used or digital FM/QPSK systems under going trials in East Europe, Canada, South America and USA. 23GHz system already fully Operational in Japan.
MMDS	Multichannel Multipoint Distribution System	2.50GHz (3.6GHz)	One-way AM/QAM. Analogue system in use in Russia, East Europa, Middle East, Ireland and USA. 3.6GHz digital QAM system in France.

3. Frequency Allocation and Applications

The frequency bands assigned to BWS, in that countries where these systems will implemented or are in exercise, are included in the frequency bands allocated for fixed services, with the exception of the 40.5 – 42.5 GHz band. The LMDS/MVDS frequency band allocation in several European and non-European countries are shown in Table 2. The major technical advantage of BWS technology over other wireless information delivery systems is its extremely wide bandwidth (see Table 2). This broadbandwidth allows LMDS and MVDS to support simultaneous services, such as voice, fax, internet, video on demand, web hosting, video conferencing tele- education, tele-medicine, tele-banking, tele-shoping, video games through a single network

4. Modulation

Modulation methods for broadband wireless BW systems are generally separated into phase shift keying (PSK) and amplitude modulation (AM) approaches. The modulation options for TDMA and FDMA access methods are almost the same. The TDMA link modulation methods typically do not

Table 2. Bandwidth of some Wireless Services.

Systems	**Bandwidth**
MVDS	2 GHz
LMDS	1 GHz
MMDS	186 MHz
DBS	500 MHz
WLAN (in the 2.4 GHz range)	83.5 MHz
Broadband PCS	30 MHz
Cellular telephone	25 MHz
Broadcast TV	6 MHz

include the 64-QAM modulation, although this might become available in the future. The FDMA access modulation methods are listed in Table 3 and are rated on an estimated scale as to the amount of bandwidth they require for a 2 Mbps constant bit rate (CBR) connection (without accounting for overhead due to ATM and FEC). Values are approximate, as there are issues involving channel filter mask roll-off factors, which can be important when providing the relationship between microwave bandwidth and data rates.

Table 3. Required Bandwidth for 2Mbps CBR Connection.

Name	**Modulation Method**	MHz **for 2 Mbps CBR Connection**
BPSK	Binary Phase Shift Keying	2.8MHz
DQPSK	Differential QPSK	1.4MHz
QPSK	Quaternary Phase Shift Keying	1.4MHz
8PSK	Octal Phase Shift Keying	0.8MHz
4-QAM	Quadrature Amplitude Modulation, 4 states	1.4MHz
16-QAM	Quadrature Amplitude Modulation, 16 states	0.6MHz
64-QAM	Quadrature Amplitude Modulation, 64 states	0.4MHz

5. Capacity Extension Method

Assuming that most of the MMDS RF channels are dedicated to an entertainment video delivery service, only a limited number of channels are available for D/S data. The subscriber capacity will likely be insufficient in larger cities and metropolitan areas. If the router, modem and communications line capacity at the PoP can be scaled up as needed, the effective D/S bandwidth must be proportionately increased. This D/S capacity increase can be realized through the use of sectorization and/or cellularization frequency reuse techniques.

Sectorization is the use of multiple narrow beam antennas at the hub to re-use the RF channels by sending different data to different groups of subscribers using the same RF channels. This requires that the two groups are sufficiently separated in azimuth. An example of sectorization is shown in Figure 3. Here we have an even number of D/S channels assigned to 6 sectored antennas of 60 degree coverage each. The two RF channel groups are labeled A and B. Channels A and B together comprise the available D/S spectrum prior to use of sectorization. The A and B channels are re-used a total of 3 times to carry 3 times the information of the non-sectored case. In an MMDS system carrying entertainment video service and data service, a separate omni- directional antenna would be used for the video service (same information to all subscribers).

Cellularization is another technique of frequency re-use. Here, multiple hub sites are used to deliver signals to groups of subscribers who are geographically dispersed over a region. Capacity increase results from sending different information from different cell sites using the same RF channels. In general a combination of sectorization and cellularization is employed. This is very different from the case of boosters employed to increase coverage in one-way MMDS systems. In the booster case, the same information is sent to all subscribers so it is possible to use the same frequencies in and out of a booster if sufficient isolation is available between receive and transmit antennas. Such isolation can be obtained by using a tall tower at the booster site to raise the receive antenna up high enough from nearby reflecting structures and provide substantial vertical separation to the booster transmit antenna which is typically mounted higher to achieve maximum coverage. In the sectored - cellular system a wider bandwidth link (trunk) is needed between the main hub site and each additional cell site to accommodate the effective multiple of bandwidth created by frequency reuse. Point-to-point microwave or fiber-optic systems are good candidates for the trunking links.

6. Components for Broadband Wireless Systems

Broadband Wireless System (BWS) is a comparatively late entry into the entertainment and television field, primarily because the technology has, until recently, been very expensive. Today BWS systems implement mainly discrete components. However, recent developments in gallium arsenide (GaAs) monolithic integrated circuit technology, at high frequencies (28 GHz, and 42 GHz), have enabled active components to be developed to the point where mass-market consumer applications have become both realistic and realisable. The trend towards more compact implementations and lower power consumption will lead designers to use more integrated functions, such as a single receiver with image rejection, the integration of

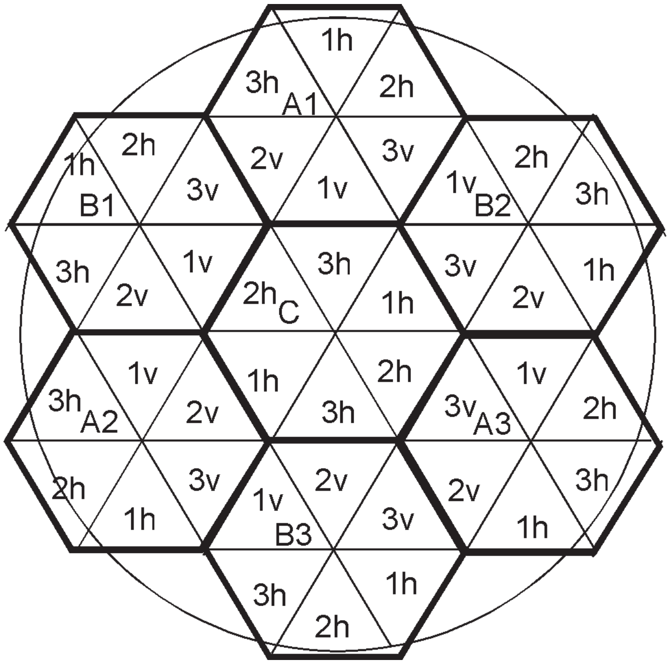

Figure 2. sectorization snd celurarization

the up converter and LO doubler, the power amplifier remaining separate. Broadband MVDS/LMDS systems and components are being produced by several manufactures such as GEC Marconi of Stanmore , Philips Broadband Wireless of Manchester, Engalco, West Yorkshire, Alpha Industries, Inc., MA, Anritsu Co., CA, Communications Techniques, Inc., NJ, Epsilon Lambda Electronics, IL, Filtronics Solid State, CA, Hewlett-Packard Co., Communication Semiconductor Solutions Div., CA, Hewlett- Packard Co., Microwave Instruments Div., CA, Hittite Microwave Corp. (Woburn, MA) (pHEMT), Fujitsu Compound Semiconductor (San Jose, CA), M/A COM, Micro Lambda, Inc. CA, Millitech Corp., MA, TriQuint Semiconductor, Inc. OR, TRW Telecommunication Products Div., CA, and Quinstar Technology, Inc., CA.

6.1. Receiving Antennas

Receive antennas must deliver consistent gain and a good directivity to minimize the detection of interference and unwanted signals arriving from directions other than antenna boresight. A minimum of 20 dB front-to-back ratio is generally assumed to be acceptable.

Wireless receive antennas generally have gains from 16 to 28 dBi although 12 dBi corner reflectors are used fairly frequently in close in situations. Antenna gain and thus size required at given location is determined by system requirements, distance from the transmitter and signal distribution requirements at the receive site. The use of higher gain antennas allows reception of signal from a given transmitter at greater distance.

In the market there are a lot of various MMDS antennas types:

1. Gregorian two reflector antennas (gain greater than 16 dB)
2. Corner reflector antenna (gain 5-15 dB)
3. Yagi antenna (gain 18 dB)
4. Parabolic antenna (gain up to 32 dB)
5. Printed planar antenna (gain 12 - 18 dB)

At the Faculty of Electronic Engineering the first three types of antennas have been developed.

In Fig. 3 layout of the realized corner antena is shown. Measured and calculated (using software package AWAS) gain vs. frequency and radiation pattern of this antena sre given in Figs. 4 and 5.

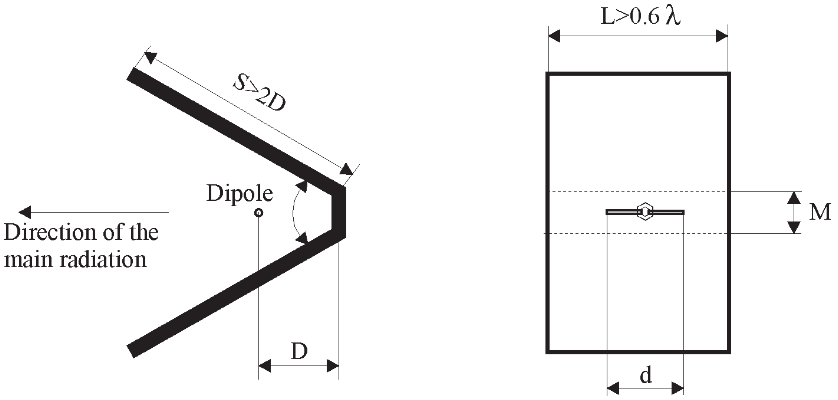

Figure 3. Corner reflector antenna.

6.2. Power Amplifiers

For alternative modulation schemes, such as 16QAM or when multiple channels are fed through the same amplifier, the amplifier must offer great linearity and cannot be operated close to saturation. Up converter for Multichannel Multipoint Distribution System (MMDS) is shown in Figure 6. The power amplifier configuration considered here is shown in Figure 7. In

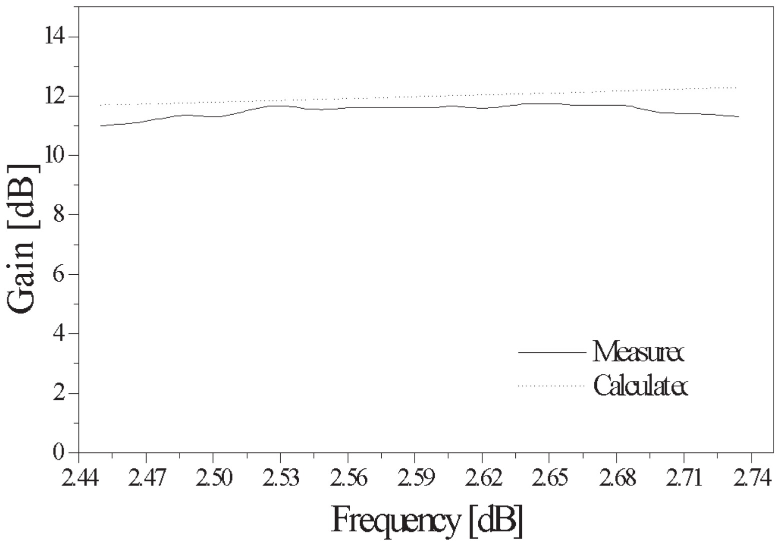

Figure 4. Measured and calculated gain of the corner antenna.

CAD simulation the MESFET model (NEC-eefet3) from HP ADS library was used as the non-linear active device. The chosen frequencies of the two main input fundamental signals are 2.5 GHz and 2.51 GHz and their input power levels are - 20 dBm. The spectrum obtained at the output is shown in Fig.8 which includes fundamental signals and the third order IM products at 2.49 GHz and 2.52 GHz.

6.3. High-Q Microstrip Resonators

In the planar designs the conductor width is modulated to produce the required variations in impedance. Step-change forms have been used in modelling and simulation exercises on microstrip High-Q resonators for 42 GHz operation. Simulated insertion loss and return loss of microstrip resonator at 42.5 GHz are shown in Figure 9.

6.4. Higd-Q Waveguide Resonators

The simulated insertion loss of the waveguide E-plane resonator using periodic metallic septa at 36.80 GHz is shown in Figure 10. The dimensions of the E-plane insert are given in the same Figure. Mode matching was

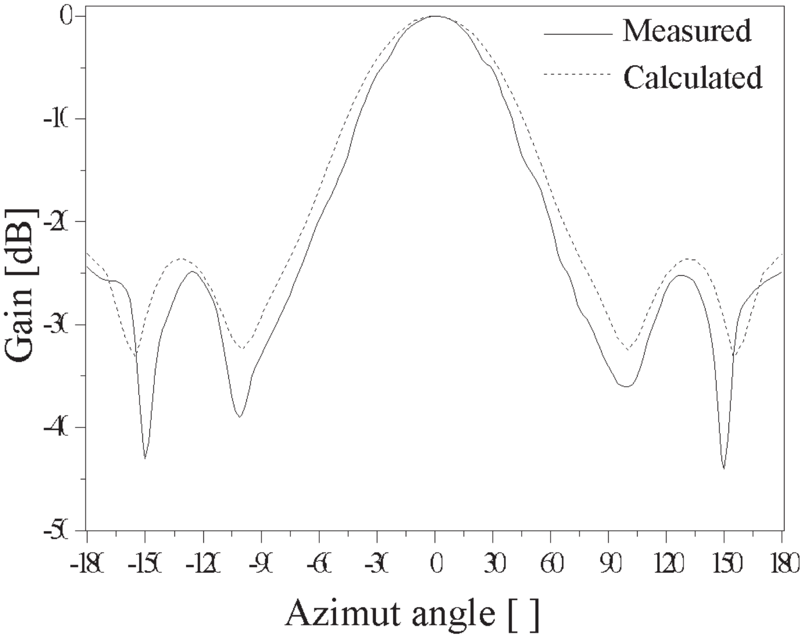

Figure 5. Radiating pattern of the corner antenna.

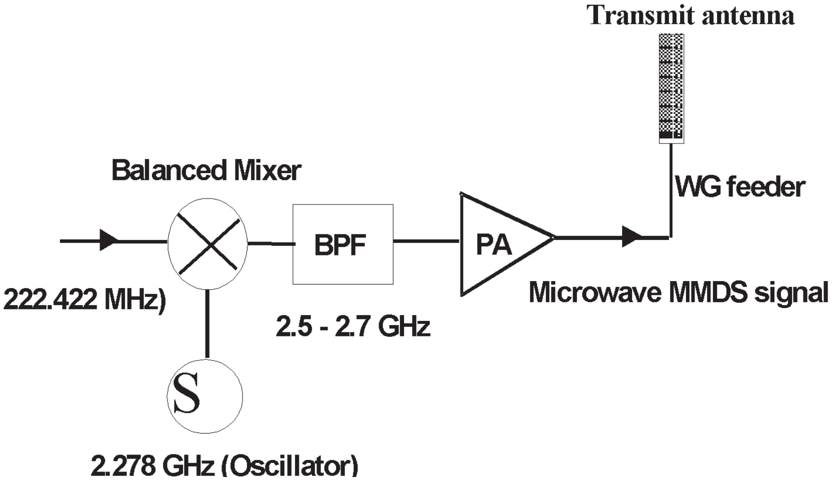

Figure 6. Up converter for MMDS system.

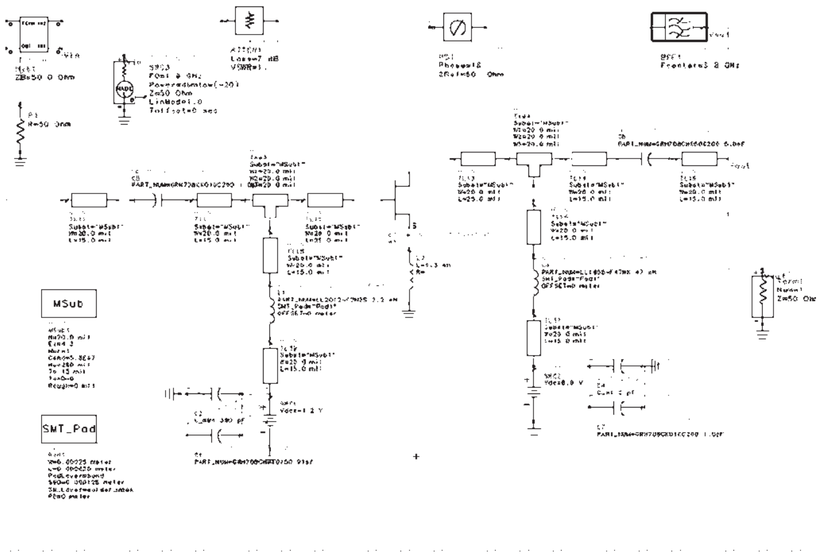

Figure 7. Functional block diagram of the simulation setup.

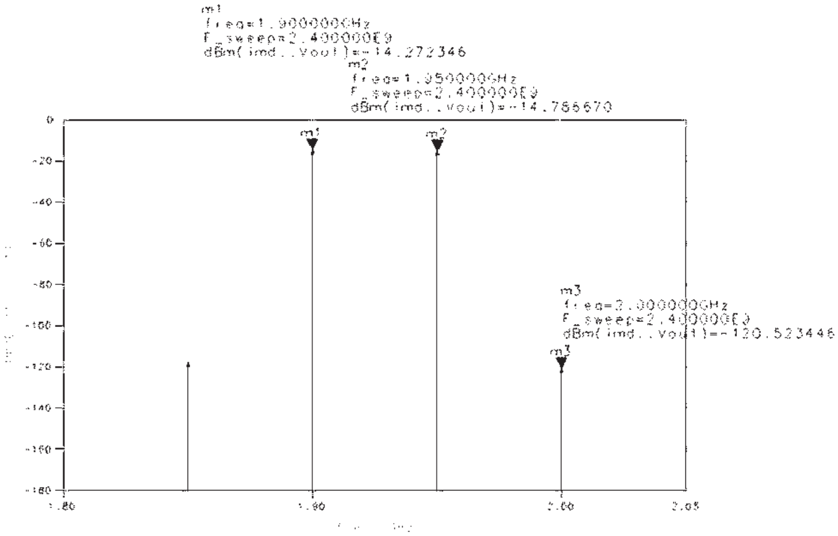

Figure 8. The simulated fundamental powers and the third order IM powers.

used for electromagnetic simulation of the behavior of the waveguide discontinuities throughout design (EPFILT) [9]. Figure 11 shows the measured transmission loss of the fabricated waveguide resonator at 36.8 GHz. The designed resonator was fabricated using brass for the waveguide housing and copper for the metal insert. The measurement was made using a HP 8510B vector network analyzer.

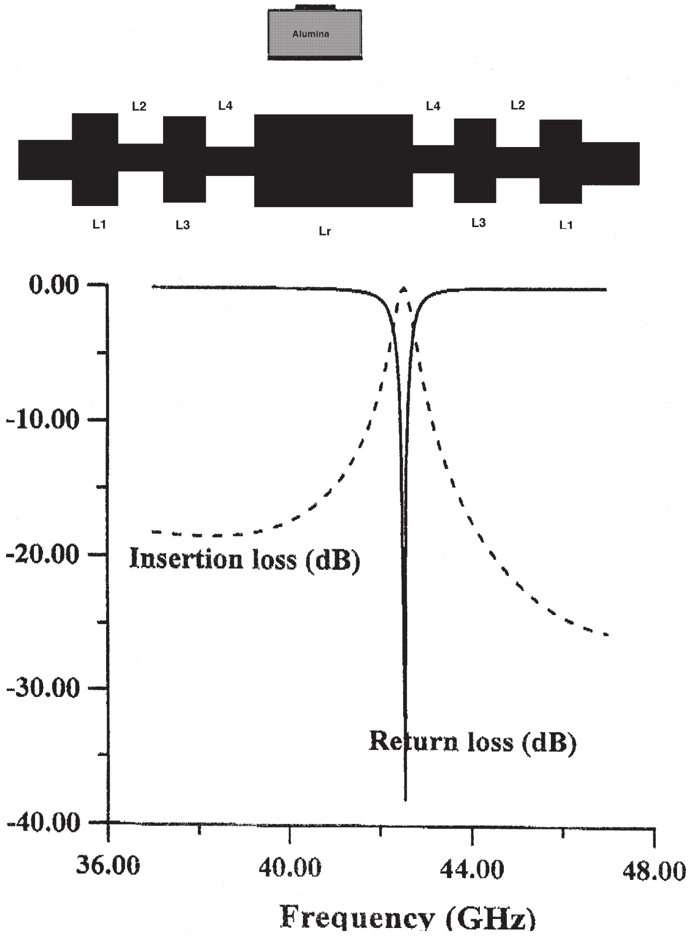

Figure 9. Shape of the microstrip resonator with periodic sections and simulated insertion loss (dashed line) and return loss (solid line) at 42.5 GHz.

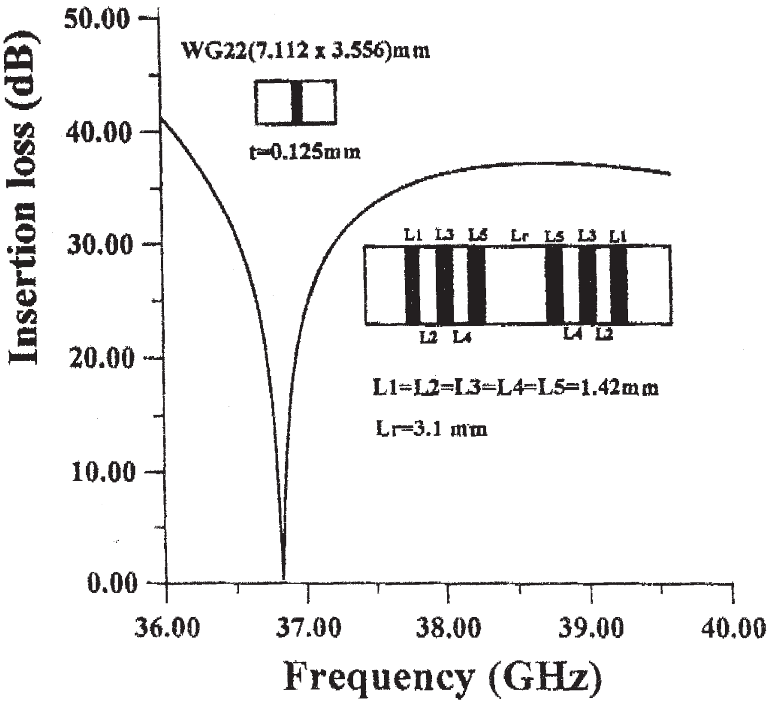

Figure 10. Shape of the waveguide E-plane resonator with periodic metal septa and simulated insertion loss of waveguide E-plane resonator at 36.80 GHz.

6.5. Filters and Diplexers

Ideal requirement to pass signals with no loss in the frequency band 27.5 – 28.5 GHz

- Type: Bandpass
- Passband: 27.5 – 28.5 GHz
- Passband flatness better than 0.2dB
- Passband insertion loss <0.5dB (smaller if possible)
- Passband return loss >20dB
- Rejection at 30.0 GHz >45 dB

Figure 12. shows the passband insertion loss calculated using the insert

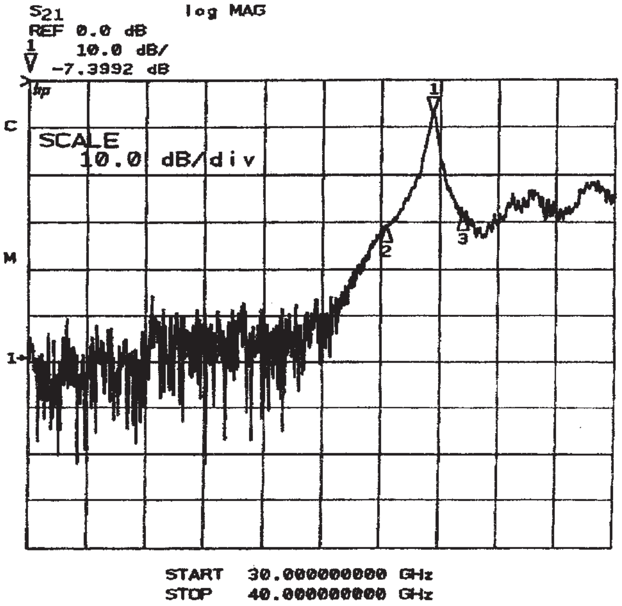

Figure 11. Measured insertion loss of waveguide E-plane resonator at 36.80 GHz.

dimensions obtained on convergence by EPFIL [9]. The dimensions of the E-plane insert are given in the same Figure. A plot of the measured insertion loss of the fabricated design (copper insert, brass housing) is shown in Figure 13. The simulated insertion loss and return loss of the waveguide E-plane bandpass filter at 40.5 GHz are shown in Figure 14. Figure 15 shows photograph of the waveguide E- plane filter for LMDS applications. In a two-way system the consumer receiver must also provide a transmit function. The are significant cost and system advantages to integrating this function into the same unit as the receiver. The diplexer is a critical mm-wave component to separate transmit and receive signal paths.

7. MMDS in Yugoslavia

In Yugoslavia due to lack of technical and law regulative MMDS does not exist. In spite of this a few teams of engineers work in this area. During the Telsiks'97 conference MMDS system operating in frequency band 2.5-2.686 GHz has been presented. During this year's conference 12 GHz digital MMDS will be presented. In this frequency band, low cost satellite receiving equipment can be used. This system can be used for analog and digital sound and TV transmission. Also the system can be used for fast Internet access.

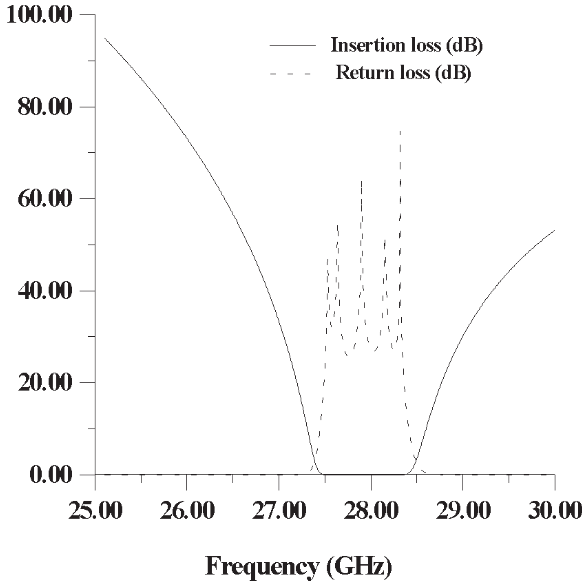

Figure 12. Calculated insertion loss (solid line) and return loss (dashed line) of the E-plane bandpass filter at 28 GHz.

Block diagram of this system is shown in Fig 16.

7. Conclusion

BWS is efficient and economical alternative way and complementary with terrestrial, cable and satellite systems for multi-channel transmission to the households and/or cable hub station. Development of digital telecommunication, with new transmission and compression (MPEG) techniques and multimedia date basic, make possible for individual and business users to receive interactive multimedia services, such as video on demand, teleeducation, telemedicine, telebanking, video conference, teleshoping, video games and other services. For MVDS above $10GHz$ E-plane filters are used. This paper has also presented some examples of the technologies which have been employed in the development of mm-wave components such as resonators, filters. and amplifiers for broadband wireless systems.

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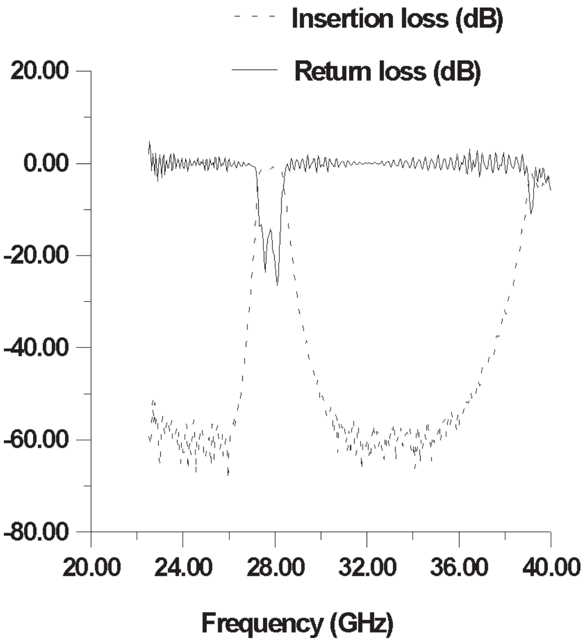

Figure 13. Measured insertion loss of waveguide E-plane bandpass filter at 28 GHz.

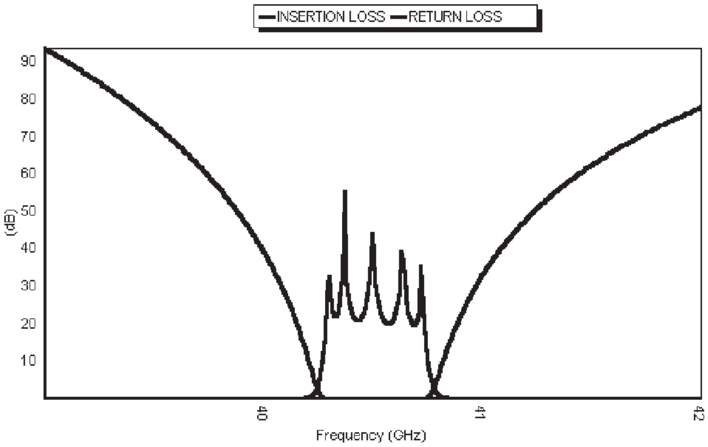

Figure 14. Simulated insertion and return losses of the E-plane filter at 40.5 GHz.

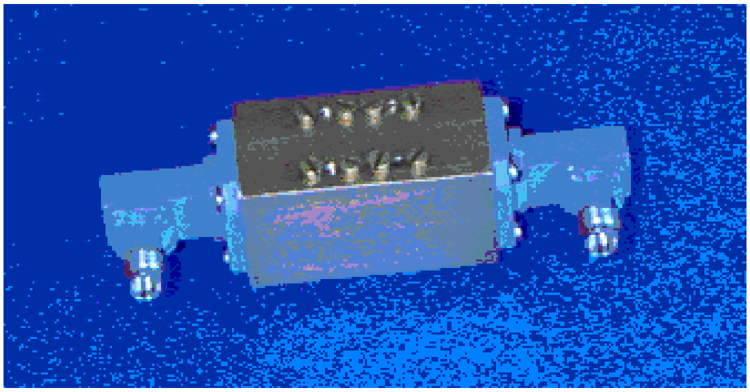

Figure 15. Photograph of the waveguide E-plane filter for LMDS.

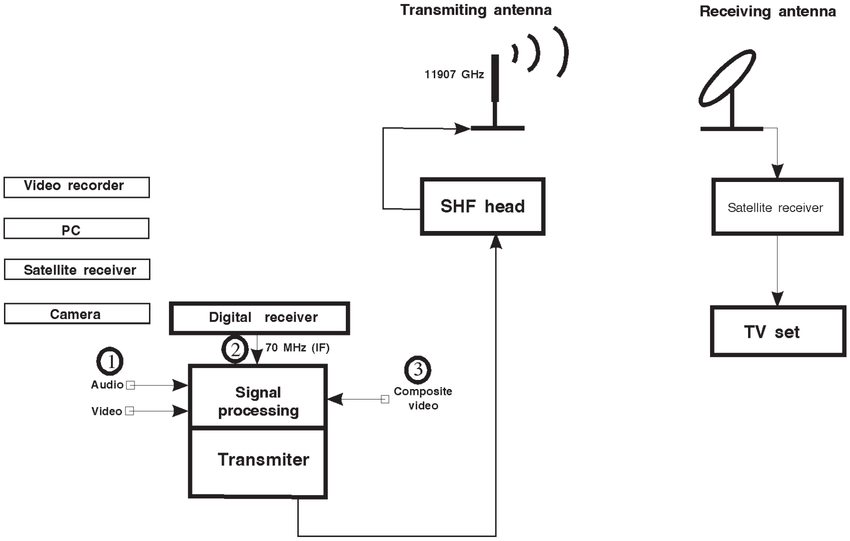

Figure 16. Block diagram of experimental 12 GHz MMDS system.

telecommunication software and devices for broadcasting, cable and satellite systems".

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