# Comparative Analysis Between Parabolic, Flat Plate and Yagi Antennas in Satellite TV Systems

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## Abstract

Analytical comparison is made between various types of antennas. Specifically, it deals with Parabolic, Flat-plate and Yagi antennas. The implementation of such antennas in the Multi-frequency Multi-channel Distribution Service (MMDS) systems is discussed with reference to Kuala Lumpur, Malaysia. Tests were conducted to ascertain the suitability of these antennas for best reception of MMDS Mega TV system. The paper seeks an approach to antenna adaptation based on the combination of various features inherent in each type, in order to establish the suitability of operation in congested areas such as city centers, high-rise building complexes and mountainous regions. Gain measurements for different values of transmitted power were conducted. Noise figures were calculated by adding the contributions of the various components of the system. The results obtained for the investigated antenna types were analyzed, and the merits and demerits were discussed. The flat plate antenna showed an overall performance better than the other types.

## 1. Introduction

There is a variety of antennas used for Satellite TV systems. Each type may be more suitable for a specific application. One of the earlier satellite TV systems is the Multi-frequency Multi-channel Distribution Service (MMDS) systems, which use wireless transmission. The signals are transmitted on the microwave frequency range (2.5-2.7) GHz. The transmitted signals are received by a special high gain antenna, which is normally placed at the top of the subscriber's home. An attached converter to the antenna converts the signal down from the microwave range to UHF, and amplifies it. The converted and amplified signal is then sent through a coaxial cable to a decoder attached to the TV set. The decoder descrambles the encoded signal and feeds the resulted compliant picture to the TV set, in a process called B-MAC encoding [1]. The Mega TV or Cableview, launched in 1996 in Malaysia, receives five channels from different satellites via Television Receive only (TVRO) antenna systems. The signals are encoded and distributed to a main transmission site, where they can be made available to subscribers, or to other transmission sites. It was the first application of a Satellite TV system in Malaysia. This typical example of MMDS transmits five satellite TV channels, which are received by LNB-Y antennas. Although the performance of these antennas may be acceptable, it does not meet expectations. They are rather bulky, cumbersome, and difficult to install and maintain. One of the major tasks of this work is to investigate the drawbacks exhibited by these antennas, in an attempt to find solutions to the problem. The main approach is to choose a more suitable type of receiving antennas.

## 2. The TV Antenna Systems

There are three receiving antennas under investigations involving technical and commercial factors namely: Low Nose Block Down Converter Yagi (LNB-Y), Quasi Log Periodic End Fire Array (QLP) and Flat Plate Antenna (FPA).

### 2.1. Noise Block Down Converter Yagi (LNB-Y)

This type of antenna is a combination representing a hybrid of 3 antenna designs; the Yagi, the Patch and the Backfire. The hybrid set up provides the 18 dB gain required by the industry standard for reflector antenna. The elements of Yagi antenna offers the benefit of reasonable performance coupled with low side and back lobes. The elements shaped as small rings (patches) mounted to a projected rod act as directors [2], which are useful in bad weather conditions. Fig.1shows the overall mounting set up. The implementation of the

LNB-Y type in Mega TV systems has shown a moderate performance in many areas in Malaysia regarding the quality of reception under various circumstances. However, in certain areas in Kuala Lumpur, the reception quality was unsatisfactory. This is primarily due to high-rise buildings in the region. The failure of Mega TV system was recorded in several other locations.

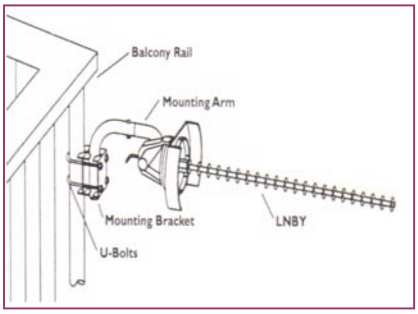


**Fig.1: The LNB-Y design with mounting**

## 2.2. Quasi Log Periodic End Fire Array (QLP) Feed Antenna

This is a relatively high gain antenna. Its high gain is due to its good impedance matching with the feed, as well as optimal focusing and illumination of the feed by the reflector [3]. The QLP is normally broad banded with a feed designed for low aperture blockage of incoming signals. The parabolic reflector, with its large focal length, has a soft focus and small cross polarization contribution. These components work together to form a complementary and reasonably well-matched system. The QLP design provides a higher interference and multipath rejection than other parabolic reflectors and dipole combinations. Fig. 2 shows a front view of a QLP antenna. However, there are some drawbacks, which will be evaluated later in the study.

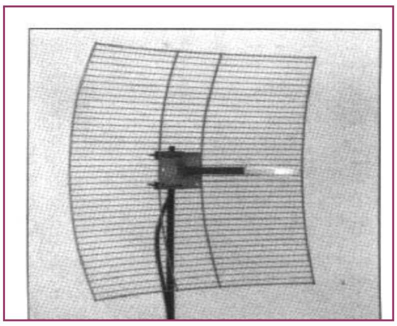

**Fig.2: A view of QLP antenna**

## 2.3. Flat Plate Antenna (FPA) for MMDS system

The Flat Plate Antenna (FPA) has proved to be quite efficient for S-band reception. However, for several decades, the implementation of FPA has been restricted to military applications, especially in Radar systems [2]. There were only a few attempts to implement this type for domestic and commercial applications. Only a few examples of such use are known, one of which is a research done in Japan [3] and the other is a recent popular application in the British Broadcasting Satellite (BBS) system [4]. A view of FPA is illustrated in Fig. 3. To verify the applicability of FPA for utilization in Mega TV system, tests were conducted on two models, namely the RS9001 and the RS9002. These FPA's are phased arrays consisting of 256 elements arranged as a rectangular or a square grid. The incident wave from the satellite arrives at the plane of the antenna with equal phase across the surface of the array. Each element receives a small amount of power in phase with the others. The feed network connects each element to the waveguide feed with an equal length. Thus, the signals reaching the waveguide are all combined and the voltages add up to enforce each other in a similar manner to rays from different parts of a parabolic dish. The difference between FPA and parabolic antenna is not in the phase across the aperture but in the amplitude, giving the array a uniform distribution. A dish has a tapered distribution. For maximum gain with a given size reflector the edge taper would be about -10 dB compared with the middle. This reduces the gain of the antenna by about 1 dB compared with a uniform distribution [5]. The latter being the optimum distribution for maximum gain from a given aperture. Tests were performed on two FPA models, the first was RS9001 and the second was RS9002. The merit for the selection is that the integrated design of the antenna, which incorporates a built-in down converter.

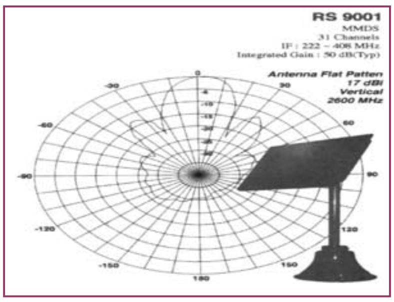


**Fig. 3: FPA (RS9001) integrated with a Down Converter, total gain is 50 dBi.**

# 3. Antenna gain

The gain *G* increases with the effective size of the antenna, which takes into account the efficiency (η), is expressed as:

$$G = 10\log\left[\log \pi^2 \eta \left(\frac{D}{\lambda}\right)^2\right] \quad dB$$

$$G = 10\left[\log\left(\frac{\pi^2 \eta}{\lambda}\right) + \log\left(D^2\right)\right]$$

$$G = 10\log\left(\frac{\pi^2 \eta}{\lambda^2}\right) + 20\log D \; dB \qquad (1)$$

Where $D$ is the diameter (m), $\eta$ is the percentage antenna efficiency (60-80) % typical, and $\lambda$ is the wavelength (m).

## 3.1. Total Noise Temperature

The total system noise temperature ($T_{SYS}$) for a ground receiving station, is the combination of noise temperatures from all contributing components in the receiving system, which include the noise introduced by the LNB, the waveguide and the effective or modified antenna noise. Fig. 4 shows the main components affecting noise temperature of the system. The plane PQ represents the reference point for the total system noise. This is usually taken to be a point immediately before the LNB or the flying connection between the wave-guide and the LNB. The effective antenna noise temperature ($T_A$) is made up of the entire noise contribution incident on the antenna, but reduced by the feed fractional transmissivity $\sigma$.

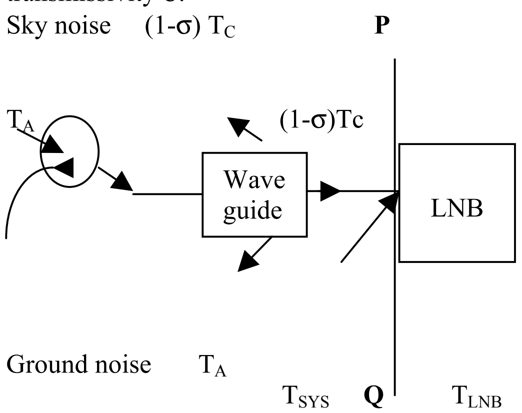


**Fig. 4: Noise Temperature components of the system**

## 3.2. Quantifying System NT

Equations (2) and (3) below can be used to quantify the total noise temperature of the system.

$$T_{SYS} = T_{LNB} + (1-\sigma)T_C + \sigma T_A K \qquad (2)$$

$$T_{SYS} = T_{LNB} + \left(1 - 10^{-0.1 A_{feed}}\right)T_C + 10^{-0.1 A_{feed}} T_A K \qquad (3)$$

Where: $T_{SYS}$ is total system noise temperature (K), $T_A$ is effective antenna noise temperature, $T_{LNB}$ is the equivalent noise temperature of the LNB (K), Tc is physical temperature of coupling (waveguide) components (k), $\sigma$ is the feed attenuation or insertion loss figure. $A_{feed}$ is the feed attenuation or insertion loss figure.

## 3.3. The Equivalent LNB NT

The term ($T_{LNB}$) in equations (2 and 3)is the overall LNB noise factor expressed as an equivalent noise temperature [2] and is a major contributor to the overall noise in a system. The noise factor expressed as a power ratio in decibels is the noise figure. The noise performance of a LNB expressed as an equivalent noise temperature in Kelvin or, can be converted to noise figure. The term equivalent noise temperature facilitates the calculation of the total system noise in accordance with equation (4):

$$T_{LNB} = 290\,(10^{(NF/10)} - 1)\;K \qquad (4)$$

Where: $T_{LNB}$ = noise temperature (K), NF = noise figure (dB)

A comparison between the measured and the computed values using the above equation for FPA RS 9001 and FPA RS9002 are given in Tables 1 and 2, together with other relevant parameters considering downconverter frequencies (2500, 2593 and 2686) MHz respectively:

| Manf. Antenna | 17 @ 2.7 GHz | | | 12 @ 2.7 GHz | | |
|---|---|---|---|---|---|---|
| Comp. Antenna Gain, $G_a$ | 16 | 16.3 | 16.7 | 12.3 | 12.7 | 13 |
| Down. Gain dB | 35 | 36.2 | 35 | 35.2 | 34.3 | 34 |
| Total Gain | 52 | 53 | 52 | 47 | 46 | 46 |
| T. Comp. Gain | 51 | 52.5 | 51.7 | 47.5 | 46.9 | 47.1 |
| NF | 1.5 | 1.2 | 1.3 | 1.4 | 1.2 | 1.2 |
| Image Rejection | 55 dB | | | 60 dB | | |

**Table 1. Measured and computed values for FPA (RS 9001 and RS 9002)**

| Manufacturers Data Antenna Gain | 18 @ 2.7 GHz | | |
|---|---|---|---|
| Computed Data of Antennas Gain | 19.8 | 20.7 | 21 |
| Downconverter Ga | 30.3 | 31.2 | 32.1 |
| T. Gain (dBi) | 51 | 52.2 | 52.4 |
| T. Computed Gain | 50.1 | 51.9 | 53.1 |
| Noise Figure (dB) | 1.7 | 1.25 | 1.5 |
| Image rejection | 55 dB | | |

**Table 2.Measured and computed values for QLP**

## 4. Comparative Analysis

The results obtained represented by the pattern of signal levels for tests involving FPA were compared with the readings obtained for tests on QLP regarding all Mega TV system channels, as in Fig's. 5 and 6. The signal strength is represented by two peaks. The high peak represents the video signal and the smaller peak represents the audio. Care must be taken in calibrating the system and the ensuing analysis of the patterns so that the audio of a particular channel is not confused with the video of an adjacent channel. One of the main features of the FPA is that terrestrial and extra-terrestrial interference is diminished when accurate calibration and tuning are performed. The wide bandwidths demonstrates the bandwidth range of FPA RS9001 and RS9002, which is large enough and provides a selection capability that prevents interference between adjacent channels. The work carried out in this paper concerns a nationwide adoption decided on the preference of one type of antenna over another. The results have shown that the FPA exhibits better performance characteristics. Therefore, it was recommended as an alternative, which is more reliable than another type initially chosen for the MMDS transmission. The grounds, on which the preference was based, are low interference, small size and weight, and good reception quality. Moreover, the measured and computed results indicate high IF rejection for FPA, which makes the reception and collection of the incident signals more precise. The QLP may be recommended for exceptional cases. From an economic point of view, the QPL is not very encouraging because it is rather bulky and requires extra cost for transportation, installation and mounting. An estimate for the installation of this type including the cost of the mountings is almost twice the cost required for FPA. It is also less suitable for the reception of digitally compressed transmission, which offers a better picture resolution.

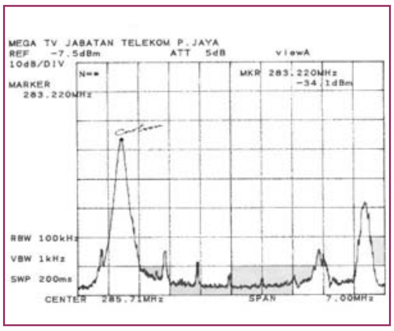


**Fig. 5 :Signal level pattern of one channel using FPA RS9001**

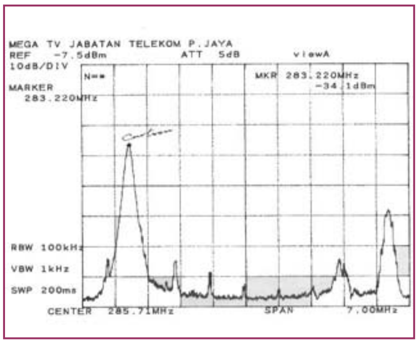


**Fig. 6: Signal level patterns of CNNI program using QLP antenna**

## 5. Conclusion

MMDS is a system, which is required to operate in certain environments that impose many limitations. High-rise buildings, hills and extreme weather conditions represent obstacles that do no not leave much space for line of sight transmission, and problems. Under these conditions, it may be difficult to make a decision that will affect large sectors of the community, without basing the decisions on proper grounds. Many types of antennas may be available in highly competitive market, all claim their suitability and superiority. In this work, an attempt has been made at resolving an issue, which may be subject to much controversy. The objective approach is to put the points of contention to the test according to proper criteria. Therefore, tests and measurements were carried out and analyzed by independent parties, to determine the preference of one type of antennas over others. Then, conclusions were drawn, based on both technical and commercial concerns. The choice was narrowed down to three types of antennas viz. FPA, QLP and LNB-Y. Out of these three types, the FPA appeared most suitable for MMDS.

## 6. References

[1] Bates, R. J.,
"Wireless Networked Communications; Concepts, Technology and Implementation",
McGraw-Hill, Inc.,
pp. 43-51. first edition 1994.
[2] Breeds, J.,
"The Satellite Book: A Complete Guide to Satellite TV, Theory and Practice",
Swift Television Publication,
Second Edition, 1992.
[3] Baylin, F., Maddox R. and, McCormack J.,
"World Satellite TV and Scrambling Methods,
Second edition, pp.5-20,
BPB Publications (1993).
[4] Stephenson, D. J.,
"Newnes Guide to Satellite TV:

installation and Reception",
Third Edition, pp.24-83,
Newnes Press (1994).
[5] Bleazard, G. B.,
"Introducing Satellite Communications",
NCC Publications,
pp.44-66, first edition, 1985.