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# Analysis & Design of Portable Video Transceiver

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## Abstract

**All of us enjoy live transmission of games, adventures and festivals etc. Generally, live recording of program is sent is sent by means coaxial cable from place of activity to VSAT equipment some where out side or activity recorded in CD is physically sent. Then it is transmitted via satellite. Portable transceiver with suitable communication range will be very handy to transmit video from place of activity to VSAT. Similarly, there are number of vital applications of portable (man-held) video transceiver like monitoring the enemy activities at borders or live reporting on earth quakes, Tsunami etc. Man-held transmitters can not transmit high powers to avoid health hazards of the operator. With increased power, equipment becomes bulky also. There is need to optimize various parameters of transceiver so that RF Power requirement is minimized. This paper analyses all important parameters of Video transceiver, develops suitable formulae/ values for them. It optimizes the parameters using a simulation model and brings out various options of designing the Video Transceiver as per the user requirements.**

***Key Words:*** *Band width of transmission, Bit Rate, Foliage Loss, Portable Transmitter, Rain Attenuation, System Noise Temperature.*

## 1. Introduction

Transmission of live Audio-Visual (A/V) programs like games, VIP functions and festivals is generally carried out by video filming by the Photographer. The camera output is coupled by a cable to the VSAT equipment placed some where out side the place of activity. At times it becomes difficult to have a cable connection and recorded video program in cassette/CD is physically sent to the VSAT. It will be very convenient for the news gathering team, if they have a mobile transceiver for wireless communication up to VSAT. There are other vital applications of mobile (man-held) A/V transceiver, like monitoring the enemy area at the borders or coverage of earth quake, floods, Tsunami etc, where road connectivity may not be available at times and communication range required may be more.

Video transmission requires larger bandwidth compared to voice transmission. If the video is transmitted without compression it requires transmission rate of at least 10 Mbps [1-3]. By using image compression and suitable type of digital modulation the bandwidth can be reduced considerably. If receiver's band width is more, received noise power will be more. To produce desired C/N ratio, the received signal power level has to be increased. In case of man-held transmitter, the RF power can not be increased beyond certain level to avoid health hazards of operating personnel [4]. Besides transmitted power, received signal power depends on path loss due the distance between transmitter and receiver and rain attenuation etc. Design requires optimization of transceiver parameters to fulfil the user requirements such as quality of video information, communication range required etc. This paper analyses all important parameters, develops formulae and values for them for simulation. It brings out a simulation model using which the designer can optimize the parameters suitably and develop a Video Transceiver according to the user requirements.

## 2. Block Diagram

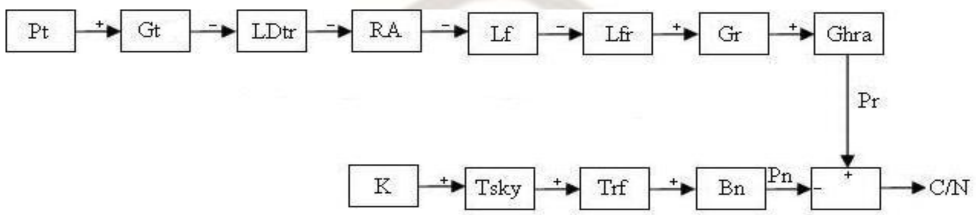


**Fig.1 Block diagram of simulation model of mobile video transceiver**

**Legend:** All Values are in dBs

Pt - Power Transmitted ;

Gt- Gain of Transmitting Antenna

LDtr- Path Loss due to Distance between Transmitter and Receiver

RA- Rain Attenuation due the rain in the transmission path

Lfr- Additional loss due to use of higher frequencies

Gr- Gain of Receiving Antenna

Lf- Foliage Loss due to trees

Ghra- Gain due to Height of Receiving Antenna

Pr- Received Power by the Receiver

K- Boltzmann's Constant

Tsky- Noise Temperature at the input of the receiver due to sky noise

Trf- Noise Temperature of the receiver RF Amplifier

Bn- Bandwidth of Noise (receiver)

Pn- Noise Power at the receiver

C/N- Carrier to Noise Ratio (at the input of the demodulator) of the receiver

The parameters shown in the block diagram are explained in succeeding paragraphs. C/N ratio is calculated using this diagram.

2.1 Path Loss due to distance between transmitter and receiver (LDtr)
There are number models to work out the path loss. To analyse and compare these models path loss has been calculated for a typical transceiver whose specifications are given below:-

(a) Transmitter Power Output : 5W
(b) Transmitter Antenna Height : 2m (Height of man)
(c) Transmitting Antenna : Omni Directional Rod Antenna
(d) Receiving Antenna : Directional, 1m dia parabolic with 60% efficiency
(e) Frequency of Operation : 2 GHz
(f) T-R Separation : 15 Km max

Summary of the path loss calculated is shown at Table No.1.

TABLE.1 Summary of path loss for suburban areas

| S No | Model | Path Loss (dBm) |
|---|---|---|
| 1 | Free Space Propagation Model | 142 |
| 2 | Log-distance Model | 188 |
| 3 | Okumura Model | 152.21 |
| 4 | Hata Model | 215.29 |
| 5 | PCS Extension to Hata Model | 222.52 |
| 6 | Lee Model | 164.7 |

As shown in the Table.1, there is a large variation in path loss calculated using existing models.

To ascertain path loss applicable, field trials have been conducted [5].

2.1.1 Path loss measured in field

Since there is no transmitter available for conducting this experiment, study has been carried out using the existing Cellular Mobile Base Station Transmitters for voice/data communication.

2.1.2 Experimental setup

The signal strength was measured at various places using the following method:-

a) A Laptop having the net monitoring software is used to monitor the signal strength. It gives, Cell Id, the signal strength in dBm.
b) A GPS is used to find out latitude and longitude (Latlong) of any place, tower etc. It also gives the distance between any two places whose Latlong is known.

2.1.3 Service conditions

a) Frequency of Operation : 900 MHz
b) Service Provider : Airtel
c) Type of Service : Voice , 2G
d) Band width of Channel : 4 KHz
**e)** Tower Height :10m Appx

2.1.4 Field conditions

**a)** Location: The Area of observations is in the outskirts of Secunderabad along Hyderabad- Karimnagar High way and Kushaiguda- Keesara road. Both are Sub-urban Areas.
**b)** Atmospheric Conditions: Dry, Normal Temperature of about 32 degree Celsius, Clear
c) Sky, Winter Season, between 10 AM and 4 PM.
d) Ground Conditions: Approximately plain, with no hills etc.
e) Foliage: There is no dense forest. Only few trees here and there.
f) Rain : No rain was there during the observation period.

2.1.5 Experimental results**:** Data obtained is tabulated in Table 2

TABLE 2. Data of signal strength measured in field (suburban area)

| S No | Cell Id | BSIC (BCCH) | RSS Idle (dBm) | Latitude | Longitude | Distance Between Serial Nos | Appox. Distance From Cell site(Km) | Path Loss Slope (dB/dec) |
|---|---|---|---|---|---|---|---|---|
| 1 | 6001 | 01(56) | -54 | 17.55971 | 78.54453 | - | 0.5 | - |
| 2 | 6001 | 01(56) | -75 | 17.56688 | 78.55403 | 1-2 | 1.79 | 37.9 |
| 3 | 6001 | 01(56) | -86 | 17.57373 | 78.56593 | 2-3 | 3.27 | 42 |
| 4 | 6001 | 01(56) | -97 | 17.59774 | 78.56861 | 3-4 | 6.69 | 35.4 |
| 5 | 50821 | 52(41) | -82 | 17.57373 | 78.56596 | - | 3.0 | - |
| 6 | 50821 | 52(41) | -87 | 17.58003 | 78.57456 | 5-6 | 4.15 | 35 |
| 7 | 50822 | 21(37) | -75 | 17.57373 | 78.56593 | - | 1.5 | - |
| 8 | 50822 | 21(37) | -84 | 17.58003 | 78.57456 | 7-8 | 2.65 | 36 |
| 9 | 843 | 56(38) | -61 | 17.59774 | 78.56861 | - | 1.0 | - |
| 10 | 843 | 56(38) | -78 | 17.61108 | 78.57073 | 9-10 | 2.5 | 42.7 |
| 11 | 53212 | 10(35) | -74 | 17.62159 | 78.57121 | - | 1.5 | - |
| 12 | 53212 | 10(35) | -84 | 17.61239 | 78.57198 | 11-12 | 2.53 | 44 |
| 13 | 37121 | 15(39) | -78 | 17.50498 | 78.62689 | - | 1.5 | - |
| 14 | 37121 | 15(39) | -90 | 17.51267 | 78.64190 | 13-14 | 3.33 | 34.6 |

Legend: BSIC – Base Station Identity Code BCCH – Broadcast Channel

2.1.6 Path loss slope calculations
The formula used for path loss slope calculation is as under:-
Path Loss (in dB) = (Path Loss Slope) ( $\log_{10}$ (T-R separation )).For Ex, Path Loss Slope 40 dB/dec means path loss will be 40 dB if T-R Separation is increased by 10 times.

2.1.7 Conclusions on path loss slope

a. From Table No 3.1 above, the path loss slope is varying from 34.6 to 44. By averaging, the path loss slope is about 38.45 dB /dec.
b. This Path loss slope is tallying with 40 dB/dec of Lee Model.

As per Lee Model, Power received in mobile environment is given by [6]

$$P_r = P_t - 156 - 40\log r_1 + 20\log h_1 + 10\log h_2 + G_t + G_m \quad (2.1)$$

Where Pt is transmitted power in dBm;

$r_1$ is T-R separation distance in miles

$h_1$ is height of transmitting antenna in feet;

$h_2$ is height of receiving antenna in feet

$G_t$ is gain of transmitting antenna in dBs; $G_r$ is the gain of receiving antenna in dBs

Therefore, the path loss, $L_{Dtr} = (40\log r1)\, dB$ (2.2)

2.2 High frequency loss (Lfr)
The expression 2.1 is applicable for frequency of 900 MHz [6]. To cater for higher frquencies, an additional loss factor (Lfr) has been incorporated in simulation model as

Lfr (db) = 10 $\log_{10}$ $(f/0.9)^2$, where f is in GHz.

2.3 Foliage loss (Lf)
Foliage Loss is the loss in received signal strength due to presence of trees (forest) in the transmission path between transmitter and receiver. There are number of models to calculate the Foliage Loss [7] based on Depth of Foliage in metres (Df). Summary of Foliage Loss is given at Table 3.

TABLE 3. Summary of foliage loss in dBs (for f=2 GHz)

| S.No. | Depth (d) In meters | Weissberger Model | Early ITU Model | Lee Model |
|---|---|---|---|---|
| 1 | 100 | 24 | 31 | 19 |
| 2 | 200 | 36 | 47 | 25 |
| 3 | 300 | 46 | 60 | 29 |
| 4 | 400 | 54 | 71 | 31 |
| 5 | 500 | * | 81 | 33 |
| 6 | 1000 | * | 123 | 39 |

*Model not applicable

Analysis:- Weissberger model is applicable for dense trees only. Early ITU model is impractical at higher frequencies[7]. Compared to these two models, Lee model is more practical for general forests (which are not very dense). As per Lee Model [6],

(a). $L_f$ increases with frequency as $(f)^4$

(b). $L_f$ is 3dB for depth 800m, Foliage away from Tx & 5dB for depth 320 m, Foliage nearer to Tx

(c). $L_f$ is 20 dB/dec at 800 MHz

The formula for Foliage Loss designed to be used for simulation is

$$L_F = \left\{ 10\log\left(\frac{f}{800}\right)^4 + 3 + 20\log\left(\frac{d}{100}\right) \right\} \quad (2.3)$$

Where f is the frequency in MHz and d is the depth of foliage in meters.

I term is included to cater for high frequencies , II term to cater for 3 dB loss at 100m as reference and the III term indicating 20 dB/dec loss is applicable for 800 MHz.

2.4 Rain attenuation (RA) in dBs

Presence of rain in the transmission path causes attenuation in received signal power called Rain Attenuation. To cater for this rain attenuation, generally a Link Margin of 6 dB is provided in addition to the minimum C/N required for the receiver demodulator for satellite link. With 6 dB Link Margin one can assure 99.5% reliability, equivalent to communication loss of 44 hours a year [8].

In addition, rain increases the antenna noise temperature. This increase in antenna noise temperature, $T_b$ is given by [8] $T_b = 280\left(1 - e^{-A/4.34}\right)K$ where A is the rain attenuation in dBs.

Analysis:- Since Slant Path of rain is more in mobile communication, due to less elevation angle, the link margin to cater for heavy rain may be increased to 10 dB. However for moderate rain 6 dB may be sufficient. For 6 and 10 dB rain attenuation the increase in antenna noise temperature works out for 23 and 24 db respectively. So the variables for simulation are taken as: For Heavy Rain – 34 dB, Moderate Rain- 29 dB and No Rain – 0 dB.

2.5 Noise power in the receiver (Pn)

Noise Power in the receiver (Pn) is given by[4] Pn = K + Ts + Bn

Where K is Boltzmann's constant, -228.6 dBW/K/Hz; Bn is the Band width of transmission and Ts is the System Noise Temperature.

2.5.1 System noise temperature (Ts)

It is given by [4], $T_s = T_{ANT} + T_{RF}$ Where $T_{ANT}$ is the Antenna Noise Temperature and $T_{RF}$ is Noise Temperature of RF Amplifier of the receiver. The antenna noise temperature depends on antenna coupling to all noise sources in its environment as well as on noise generated within the antenna. Antenna elevation affects the antenna noise temperature. Antenna noise temperature decreases with increase of elevation [8]. The antenna noise can be divided into two types of noise according to its physical source: noise due to the loss resistance of the antenna itself and noise, which the antenna picks up from the surrounding environment. Antenna Noise Temperature varies between10 K and 100K depending on the frequency and elevation angle. At 2 GHz, it is 100K max. Atmospheric noises just above the surface of the earth will be affecting the antenna noise temperature. The noise temperature at approximately zero elevation angle (horizon) is about 100 to 150 K [8] .

Analysis:- For simulation, we may consider that maximum antenna noise temperature to be about 150K. Secondly, Noise Temperature of RF amplifier is depending on the quality of the receiver. For good quality receiver $T_{RF}$ varies from 60K to 120K . So the maximum value Ts, 270K (24 dB) is used for simulation.

2.6 Band width of transmission

Band width of transmission depends on the Type of Signal, Quality of Signal required, Resolution and Type of Modulation scheme.

2.6.1 Type & quality of Signal**:** The data rate of digital video signal varies depending on the resolution and compression ratio. For the sake of analysis, the Type of Signal can be represented by the programs Sports, News or Film. Type & Quality of Signal along with resolution decide the Bit Rate (Rb) [10] as shown in Table 4.

TABLE 4. Relation of signal, quality and bit rate

| S.No. | Signal | Quality | Resolution | Bit Rate (Rb) |
|---|---|---|---|---|
| a) | Sports | Good | 704 X 576 | 6 Mbps |
| b) | Sports | Average | 544 X 576 | 4 Mbps |
| c) | News | Good | 544 X 576 | 3 Mbps |
| d) | Film | Good | 544 X 576 | 2 Mbps |
| e) | Film | Average | 352 X 576 | 0.7 Mbps |

2.6. 2 Type of modulation & Band width

Band width required varies with type of modulation as under [11] :-

a) QPSK - Rb/2
b) 8 PSK - Rb/3
c) 16 PSK - Rb/4
d) 64QAM - Rb/6

2.7 C/N ratio required at the input of receiver

Generally, C/N ratio of 18 dB is considered very good [6]. With technological improvements in the receiver even 10 dB is considered adequate for good reception.

2.8 Communication path

Communication Path (CP) has been included in the variables, which may be either 'mobile environment' or 'free space'. When the height of receiving antenna is sufficiently high (about 120m or so) and if there are no obstacles in the transmission path, path loss slope may be of free space rather than mobile environment [6].

Secondly, there is a possibility of using the video transceiver as a repeater, receiving from a field source and transmitting to a GEO satellite, via free space.

## 3. Simulation program

The model is simulated in MATLAB. This algorithm and the formulae/ values developed for various parameters can be used by the designer to optimize transmitter power output, size and height of receiving antenna etc depending on type and quality of program to be transmitted. By varying the inputs one can obtain essential C/N ratio so that the communication is achieved in desired conditions of user.

3.1 Simulation results

Table 3. Results of simulation

| | Transmitter | | | | | Comn Path | | | | Receiver | | Results | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SNo | Prog | Qual | Mod | Pt W | f GHz | Dtr Km | RA | Df m | CP | D m | Hra m | Rb Mbps | Bn MHz | Lp dB | Pr dBm | Pn dBm | C/N |
| 1 | Sports | Good | QPSK | 5 | 2 | **1** | N | 0 | M | 0.2 | 6 | 6 | 3 | 125 | -67 | -110 | 43 |
| 2 | Sports | Good | QPSK | 5 | 2 | **2** | N | 0 | M | 0.2 | 6 | 6 | 3 | **137** | **-79** | -110 | **31** |
| 3 | Sports | Good | QPSK | 5 | 2 | **3** | N | 0 | M | 0.2 | 6 | 6 | 3 | **144** | **-86** | -110 | **24** |
| 4 | Sports | Good | QPSK | 5 | 2 | **1** | N | **100** | M | **0.6** | 6 | 6 | 3 | 144 | **-77** | -110 | **33** |
| 5 | Sports | Good | QPSK | 5 | 2 | 1 | **M** | **0** | M | 0.6 | 6 | 6 | 3 | **154** | **-87** | -110 | **23** |
| 6 | Sports | Good | QPSK | 5 | 2 | 1 | **H** | 0 | M | 0.6 | 6 | 6 | 3 | **159** | **-92** | -110 | **18** |
| 7 | Sports | Good | QPSK | 5 | 2 | 1 | **M** | **100** | M | 0.6 | 6 | 6 | 3 | **176** | **-106** | -110 | **4** |
| 8 | **Film** | **Average** | **64PSK** | 5 | 2 | 1 | **H** | 100 | M | 0.6 | 6 | **0.7** | **0.11** | **178** | **-111** | **-124** | **13** |
| 9 | **Sports** | **Good** | **QPSK** | 5 | 2 | **15** | **N** | **0** | M | 0.6 | **10** | **6** | **3** | **172** | **-100** | -110 | **10** |
| 10 | **Film** | **Average** | **64PSK** | 5 | 2 | 15 | N | 0 | M | 0.6 | 10 | **0.7** | **0.11** | 172 | -100 | **-124** | **24** |
| 11 | Sports | Good | QPSK | 5 | 2 | 15 | **H** | 0 | M | 0.6 | **60** | 6 | 3 | **182** | **-95** | -110 | **15** |
| 12 | **Film** | **Average** | **64PSK** | 5 | 2 | 5 | **M** | 500 | M | 2 | 60 | **0.7** | **0.11** | **215** | **-117** | **-124** | **7** |
| 13 | Film | Average | 64PSK | **10** | 2 | 5 | M | 500 | M | 2 | 60 | 0.7 | 0.11 | 215 | **-114** | -124 | **10** |
| 14 | Film | Average | 64PSK | **5** | 2 | 5 | M | 500 | M | 2 | **100** | 0.7 | 0.11 | 215 | **-113** | -124 | **11** |
| 15 | Film | Average | 64PSK | 5 | 2 | **3** | M | **300** | M | **0.6** | 100 | 0.7 | 0.11 | **201** | **-110** | -124 | **14** |
| 16 | Film | Average | 64PSK | 5 | 2 | **2** | M | **200** | M | **0.2** | 100 | 0.7 | 0.11 | **191** | **-109** | -124 | **15** |

**Legend : Bold** indicates the changed data as compared to last serial number
**SNo-** Serial Number
**Prog-** Type of Program
**Qual-** Quality Required
**Mod-** Type of Modulation
**Pt W-** Transmitter Power
**f GHz-** Frequency;
**Dtr Km-**Distance between Transmitter and Receiver in Km
**RA-** Rain Attenuation :
**H-** Heavy, **M-** Moderate, **N-** No Rain
**Df m-** Depth of Foliage in metres in transmission path
**CP-** Communication Path :
**M-** Mobile, **F-** Free Space
**D m-** Diameter of Receiving Antenna
**Hra m-**Height of Receiving Antenna
**Rb Mbps-** Bit Rate
**Bn MHz-**Bandwidth
**Lp dB** path loss in dBs
**Pr dB-**Power Received
**C/N-** C/N Ratio available

## 4. Discussion of results (with reference to Table 3)

The results show that it is possible to design a mobile video transceiver for various applications, in different conditions as under:-

4.1 For News Reporting-

1. S. No 1, 2 and 3, shows that communication up to 1- 3 Km is possible with Transmitter Power of 5 W **if Foliage Loss is negligible and there is no rain.**

2. S. No 4 shows that communication up to 1 Km is possible with Transmitter Power of 5 W, even **if depth of foliage is up to 100 m, but no rain should be there.**

3. S. No 5 and 6 show that communication up to 1 Km is possible with Transmitter Power of 5 W, even **in heavy rain, if Foliage Loss is negligible.**

4. S. No 7and 8 indicate that communication up to 1 Km is possible with Transmitter Power of 5 W, **even in heavy rain and depth of foliage is up to 100m, but with a compromised video signal.**

4.1.1 Conditions in which communication not Possible

1. S. No 12 indicates that communication is **Not OK**, even up to 5 Km with 5 W with Receiver Antenna Height to 60 m, **if depth of Foliage is 500m**, even in **Moderate rain.**

4.2 For Defence Applications like enemy area monitoring with un-manned Aerial Vehicle (UAV), etc.

1. S. No 9 and 10 show that communication is **Good** up to 15 Km with Transmitter Power of 5 W **with Receiver Antenna Height to 10 m and with compromised video signal**, if no Foliage Loss is there and no rain is there.

2. S. No 11 shows that communication is Good up to 15 Km with Transmitter Power of 5 W if Receiver Antenna Height is 60 m, even in **Heavy** rain if no Foliage Loss is there.

3. S. No 13 shows that communication **is possible** up to 5 Km with Transmitter Power of 10 W with Receiver Antenna Height to 60 m, **if depth of Foliage is 500m**, even in **Moderate rain.**

4. S. No 14, 15 and 16 show that communication is possible for 2-5 KM, with 5W in moderate rain and varying foliage, **if antenna height is 100m** by optimizing the parameters of the transceiver.

## 5. Conclusion

1. This paper brings out all important aspects in the design of a Video Transceiver and developed expressions for the factors affecting the design.
2. The Simulation program makes the job of designer very simple as he can optimize the parameters and check for its performance before manufacturing the transceiver.
3. Video transmission from place of activity to Satellite earth station so far is through coaxial cable or a recorded program in CD is transmitted. This paper shows that it is possible to achieve the communication between a mobile (man-held) video transmitter from place of activity and a static (or vehicle mounted) Satellite Earth Station Transceiver for an optimum range with desired C/N ratio by varying the parameters of the transceivers suitably.
4. By using the simulator developed, it is possible to design a transceiver for news reporting and also for defence applications.

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