Internal Technical Report
on
DTH – GMRT Co-existence

A RFI Survey for Direct to Home System

[redacted]

By

Yogesh B. Karandikar
Graduate Trainee

Under guidance of:

Mr. T. L. Venkatsubramani

Giant Meterwave Radio Telescope,
Khodad.

Contents

1. Overview of DTH Systems

Direct to Home are nothing but the Direct Broadcast Satellite Television and Radio Systems. Geostationary satellites play an important rôle for DTH systems. In general, DTH service is the one in which a large number of channels are digitally compressed, encrypted and beamed from very high power Geostationary satellites. The programs can be directly received at homes. Also, DTH transmission eliminates local cable operator completely, since an individual user is directly connected to the service providers.

An individual user has a small dish usually 45 to 60cm in diameter and Low Noise Block Converter (LNBC) pointed towards satellite. At home digital receiver i.e. Set top box is connected to TV which receives digitally multiplexed channels from LNBC and gives RF output for TV.

The satellite transmission is usually in Ku- Band. The digital channels are first multiplexed and then QPSK modulated before transmission. The small dish along with LNBC receives the signals and LNBC converts these Ku band signals to Intermediate Frequency based on the local IF which is typically 10.7GHz. Now, the set top box receives the down-converted satellite signals and performs the demodulation and de-multiplexing and finally D to A conversion before making signal competent to TV.

The DTH receivers available in the Market are affordable and the use of such systems is now a days increasing dramatically in urban as well as ruler areas.

DD Direct: DD Direct is launched by Doordarshan. It operates from NSS-6 Satellite and gives 33 free to air channels and 13 radio channels. The transmission covers most of the India. The cost of the Dish, LNBC and Set top box is around Rs. 2500/-. With this setup only free to air channels are visible.

Dish TV: Dish TV is launched by Essel Group. The Dish TV has different set top box with Smart card facility to decode paid channels. The cost of the unit is around Rs. 4000/-. So user can watch paid as well as free channels and radio programs. The user has to pay monthly rental for paid channels. The entire 'Zee Network' channels are available on Dish TV. Dish TV Transmission is also from NSS- 6 Satellite.

Specifications of NSS-6 Satellite:
Location: 95 degree East
No. of Ku-Band Transponders (36MHz wide): 60
Saturated EIRP: 44-55 dBW.
Ku Band Uplink: 13.75 to 14.5 GHz
Ku Band Down links: 10.95 to 11.2 GHz
11.45 to 11.70 GHz
12.50 to 12.75 GHz
Modulation Type: QPSK
Symbol Rate: 27.5 Mb/s.
Downlink for DD Direct: 12815, 12534,12898 GHz.
Look Angles for GMRT: Azimuth= 130.51 degree from North.
Altitude= 57.26 degree

2. Antenna & LNB Specifications

Antenna Specifications: -

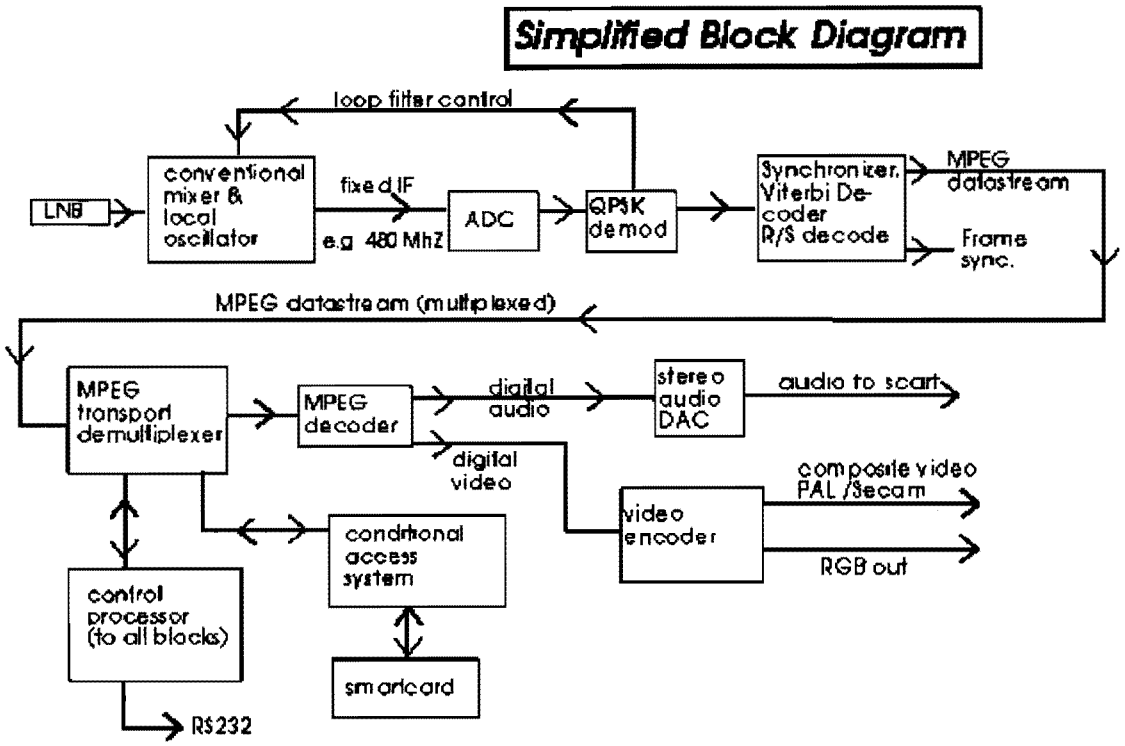
Reflector Size	65 cm
Type	Offset Feed
Frequency	10.7 to 12.75GHz
Antenna Gain	> 36.75dBi @12.75GHz
3dB Beam width	< 3.2 degree
10dB Beam width	< 5.2 degree
Aperture efficiency	> 70%
Surface Accuracy	< 0.01"
Material	Steel/ Aluminum
Elevation Angel Range	15 to 50 degree
Cross Polar Discrimination on major axis.	>27dB
VSWR max	1.3
Noise Temperature	< 35 Kelvin
Offset Angle	25 degree
F/D ratio	0.6

LNB Specifications: -

i/p Range	10.7GHz to 12.75GHz
Local Oscillator	9.75GHz or 10.6GHz
Noise Figure	0.5dB
Noise Temperature	35 Kelvin @ 290 degree
Gain	55dB

3. Set Top Box

The typical block diagram of the Set top box is as shown in following figure,



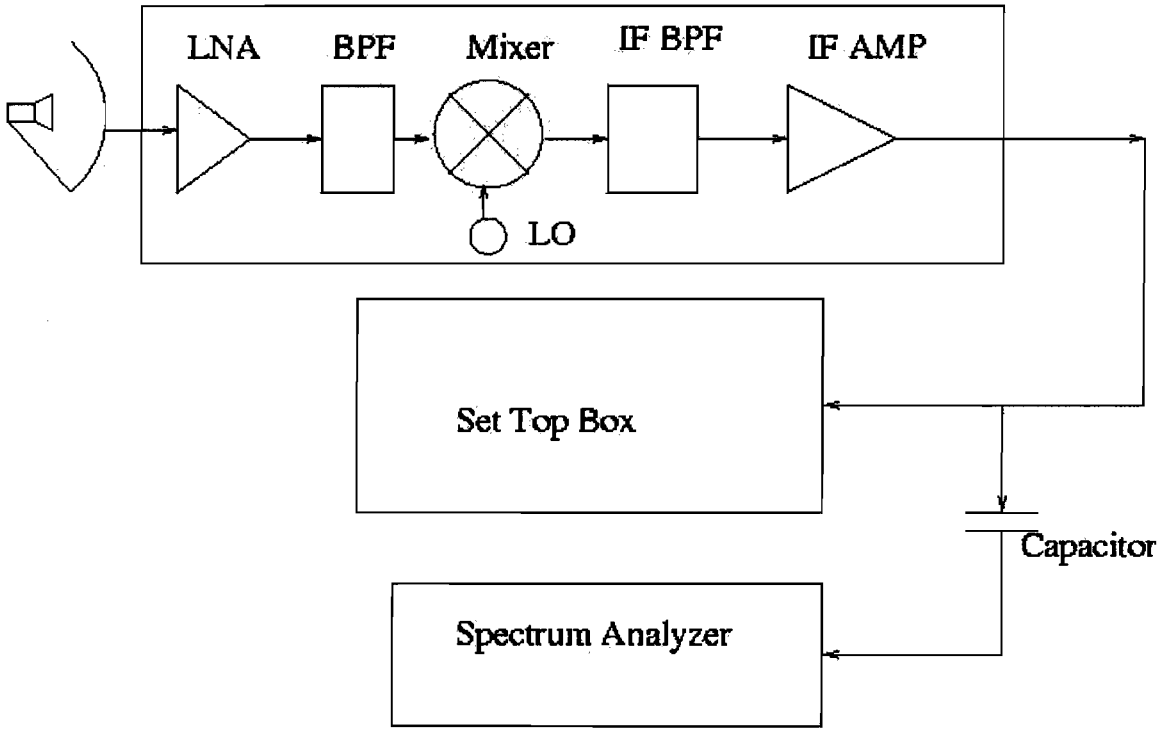
As per the diagram, the set top box accepts the entire down converted band and separates out the individual transponder frequency. Then signals are first converted to fixed IF and then QPSK demodulated. The bandwidth of QPSK signals is 27.5 Mhz as the bit rate is 27.5 Mb/s. It is observed that 11 digital channels are multiplexed in 27.5 Mhz bandwidth. The power supply for LNB, polarization selection signals as well as LO setting signals are send by the set top box itself by using the same cable between the LNB and set top box.

After the QPSK demodulation, the digital bit stream obtained contains several multiplexed channels as well as error control bits. The bit stream is processed to correct and detect errors, de-interleaved, and decrypted. A digital demultiplexer then extracts the bits for wanted channel, and send them to MPEG decoder, and finally generates analog Audio and Video signals with D/A converters to drive TV set.

The paid channels are encrypted, and a smart card having the correct key for decryption is required to view the paid channels. The key is provided by the paying monthly rent by the user.

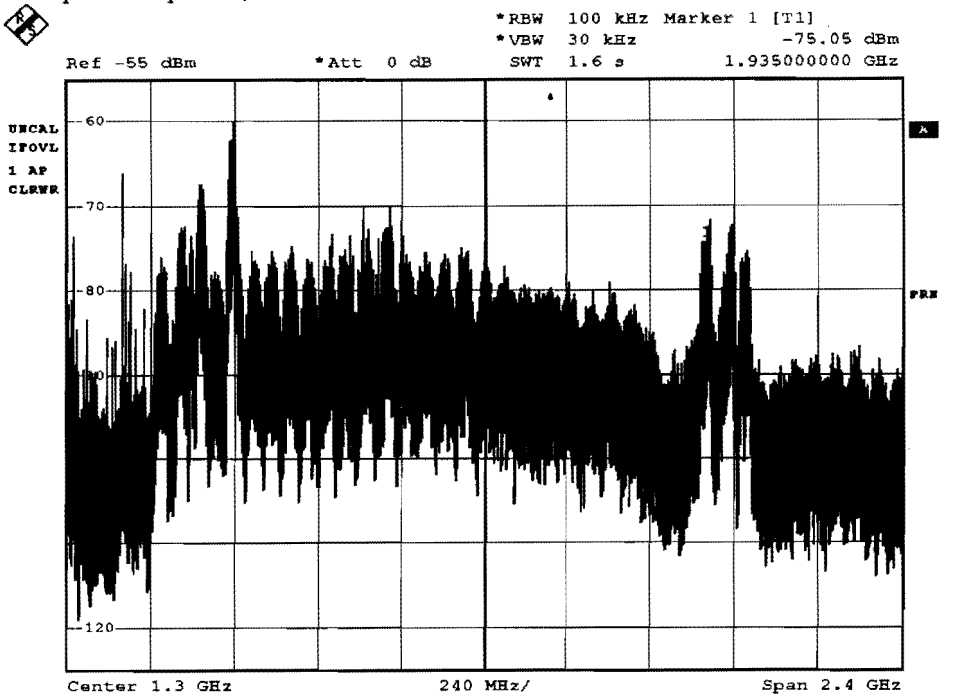
4. Various Spectrums in LNB Cable

For estimating possible RFI from DTH systems, one must know the exact spectrum available in the cable from LNB (Located at roof top) and the set top box (Located in the house). Because the chances of radiation are from the cut to the cable, bad connector installation or bad cable itself. So to understand the spectrum, we have tapped the cable as shown in the following block diagram.



The Set Top Box we used has brand name 'Koship' and the LNBs are 'Colorado', 'Gardner', 'Broadcom' make.

Koship Set Top Box, Broadcom LNB: Horizontal Polarization



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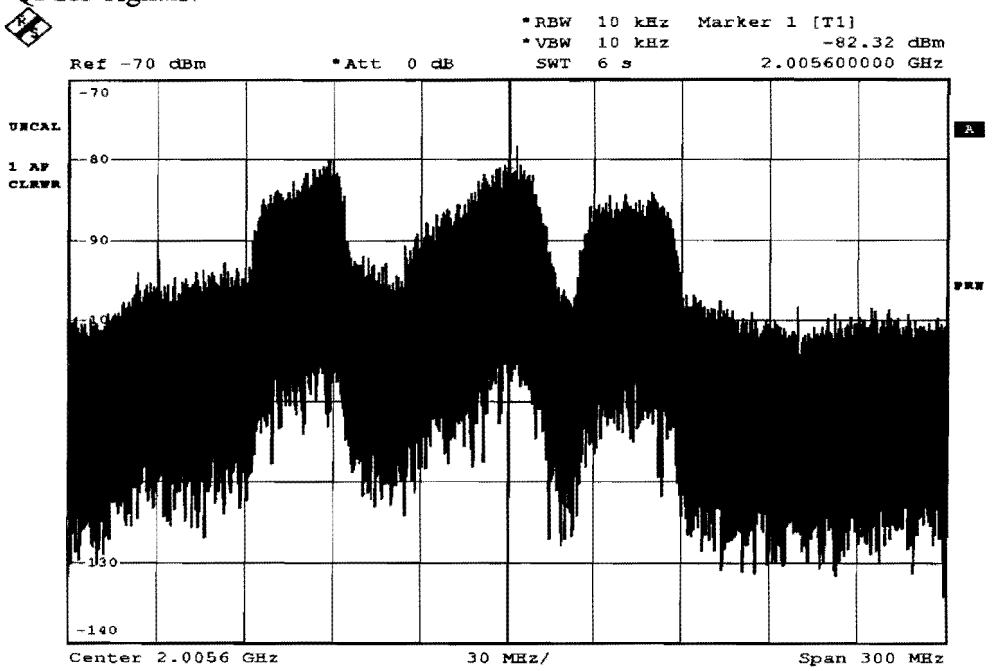
QPSK Signals:



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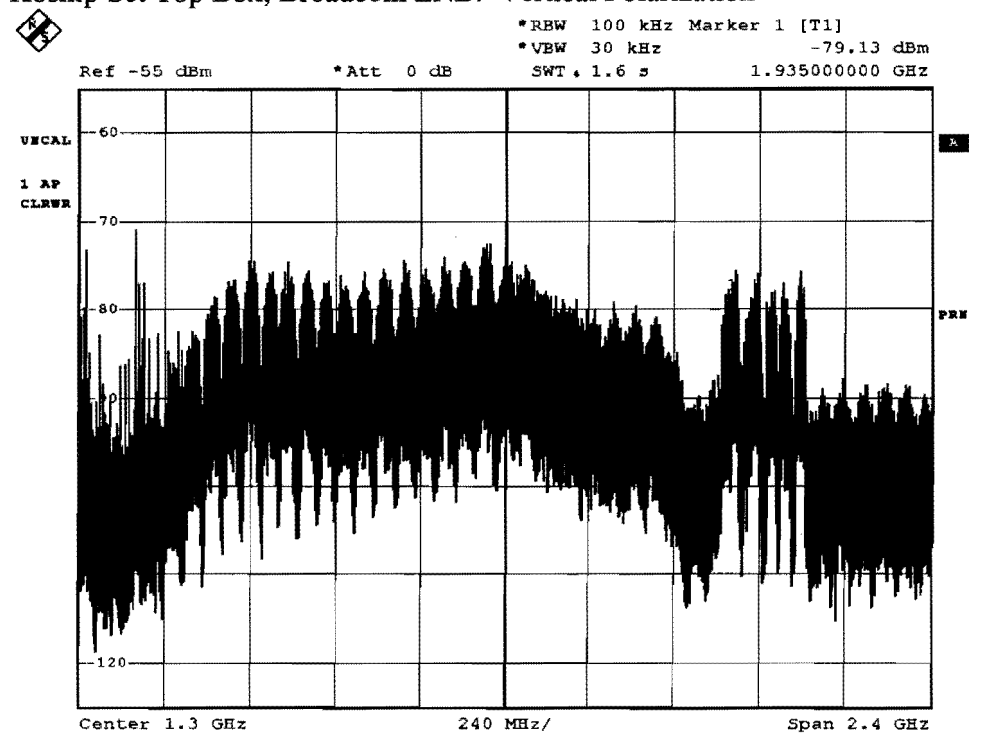
Koship Set Top Box, Broadcom LNB: Vertical Polarization



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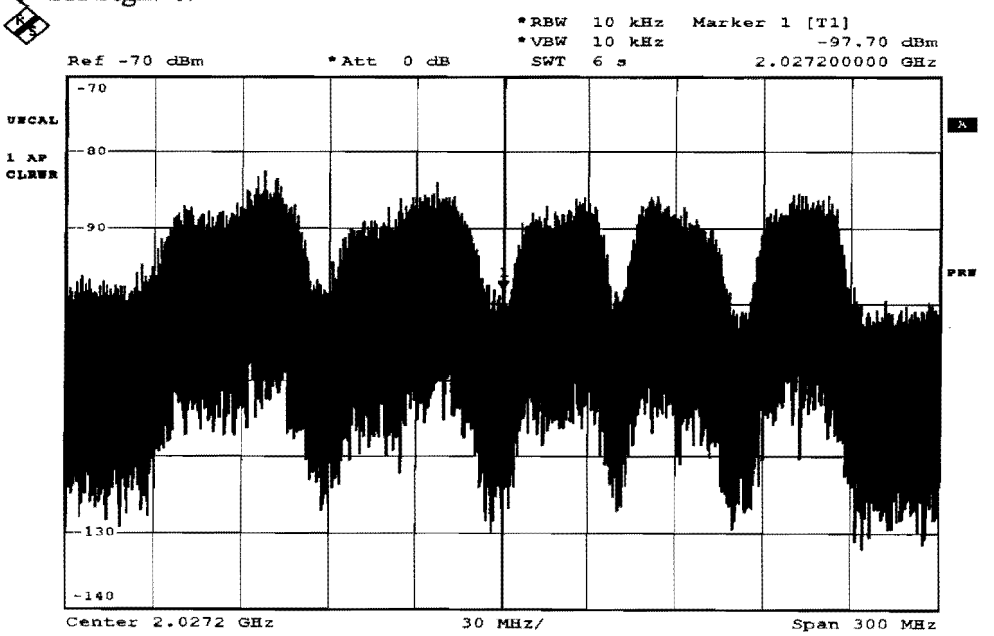
QPSK Signals:



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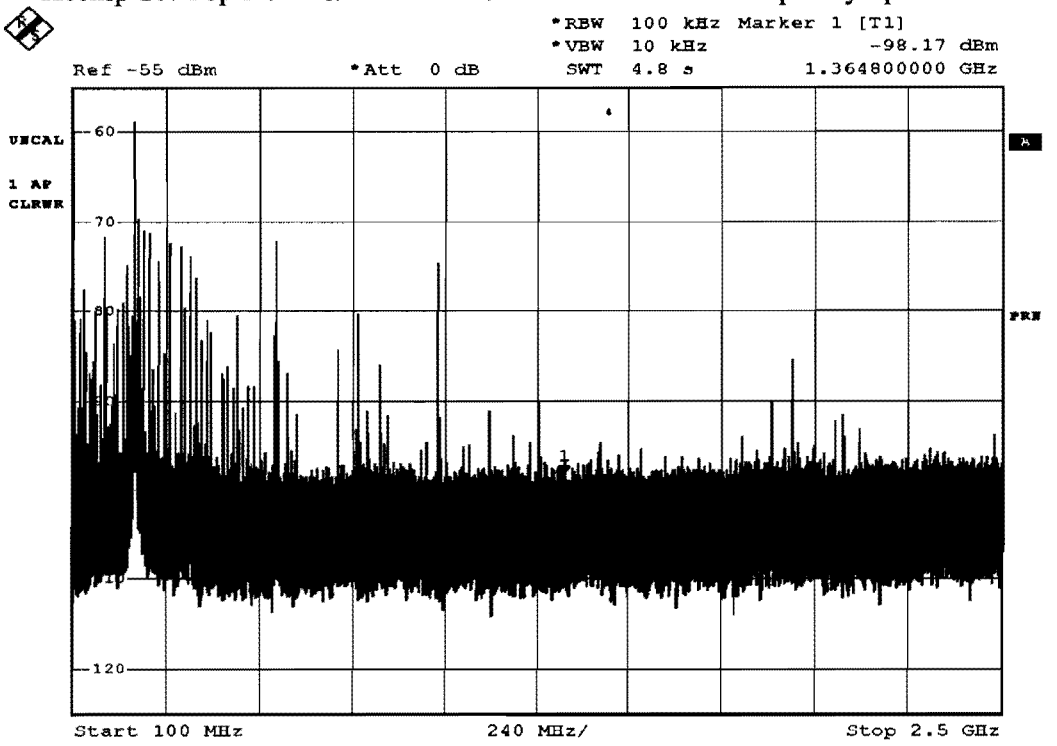
Koship Set Top Box with LNB disconnected: Different Frequency Spans



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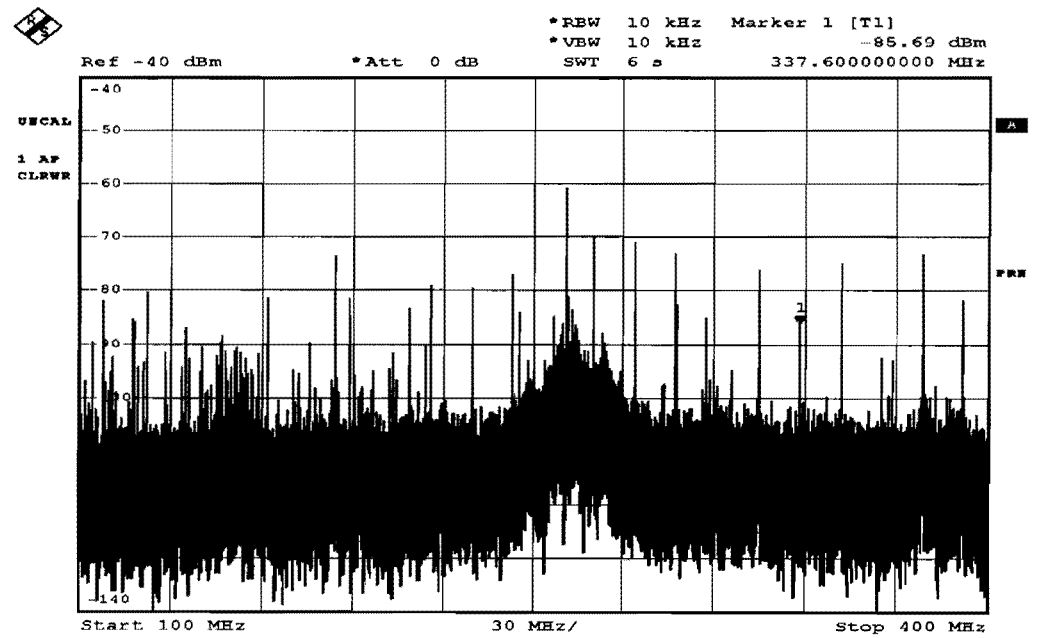

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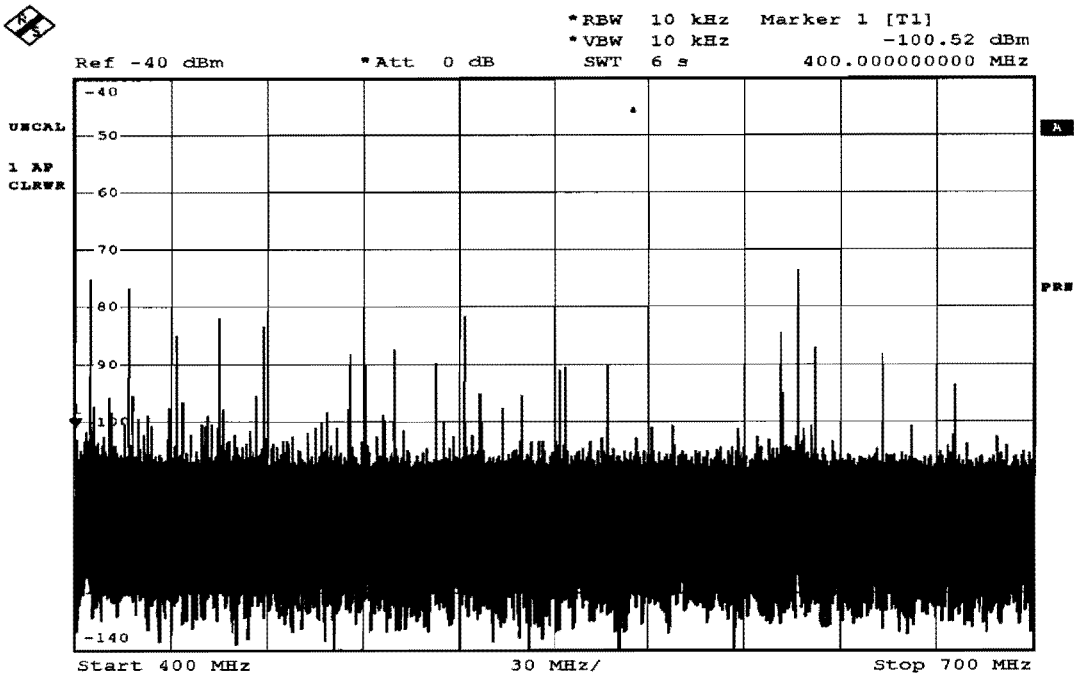

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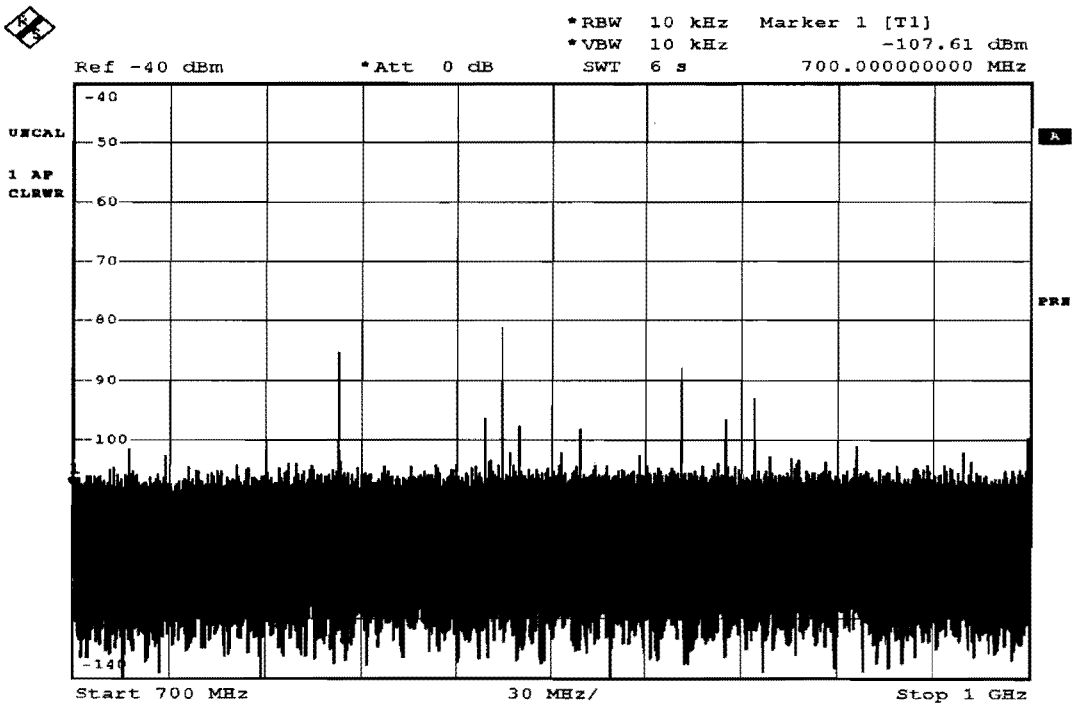

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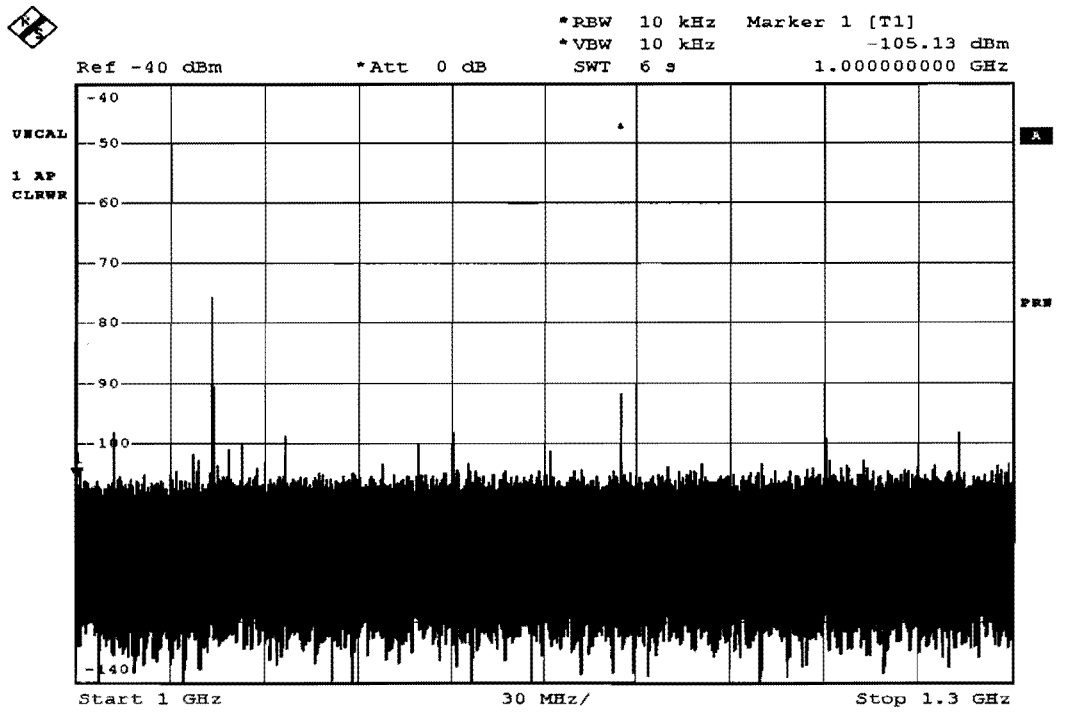

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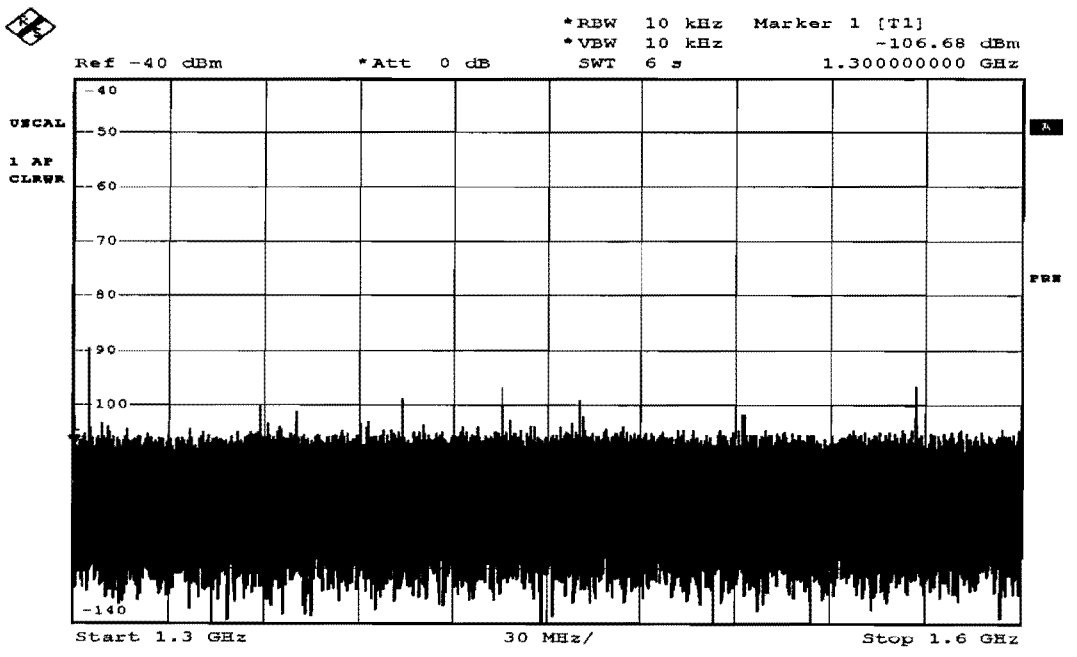

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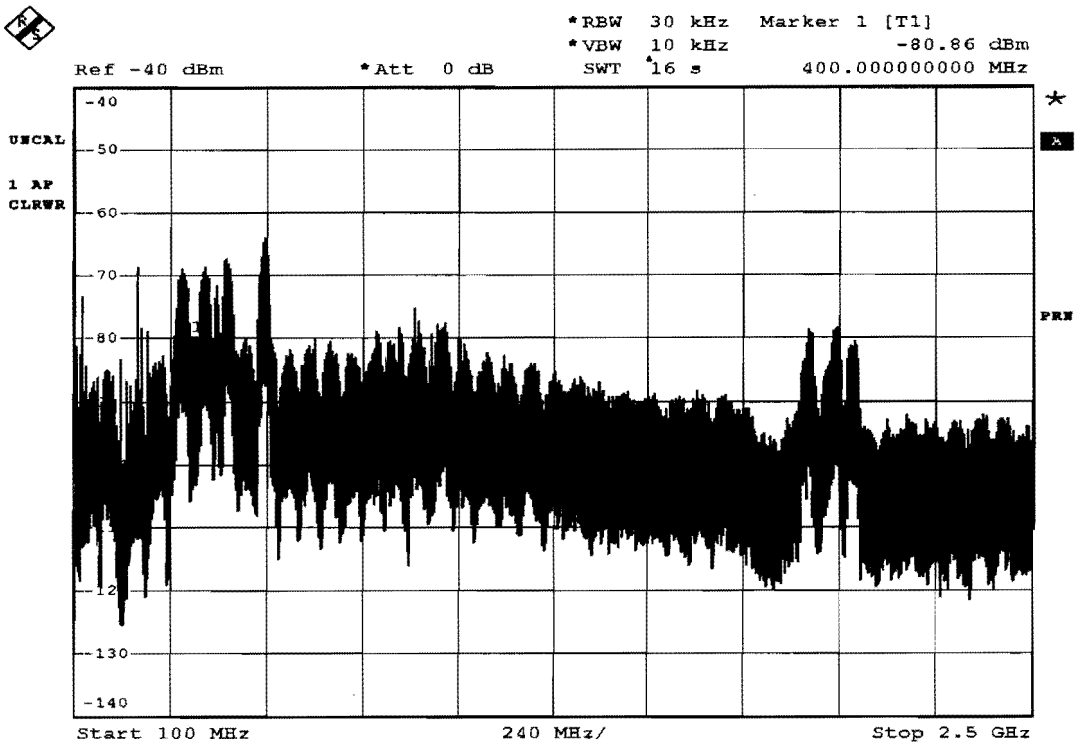
Koship Set top box with Gardner LNB: Horizontal Polarization



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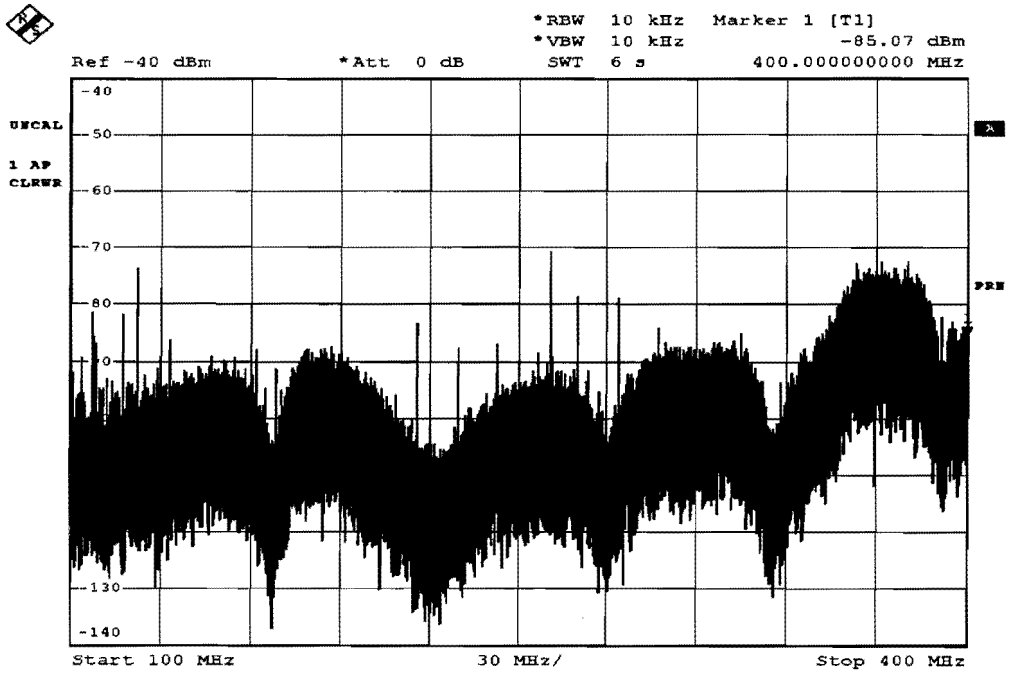

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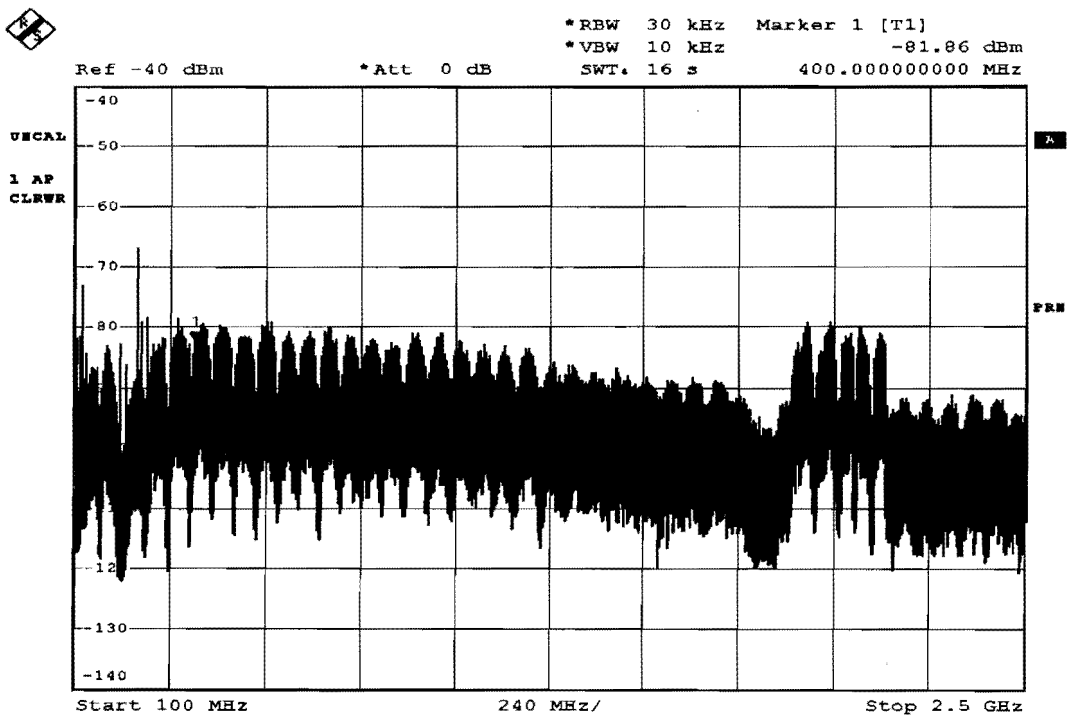
Koship Set top box with Gardner LNB: Vertical Polarization



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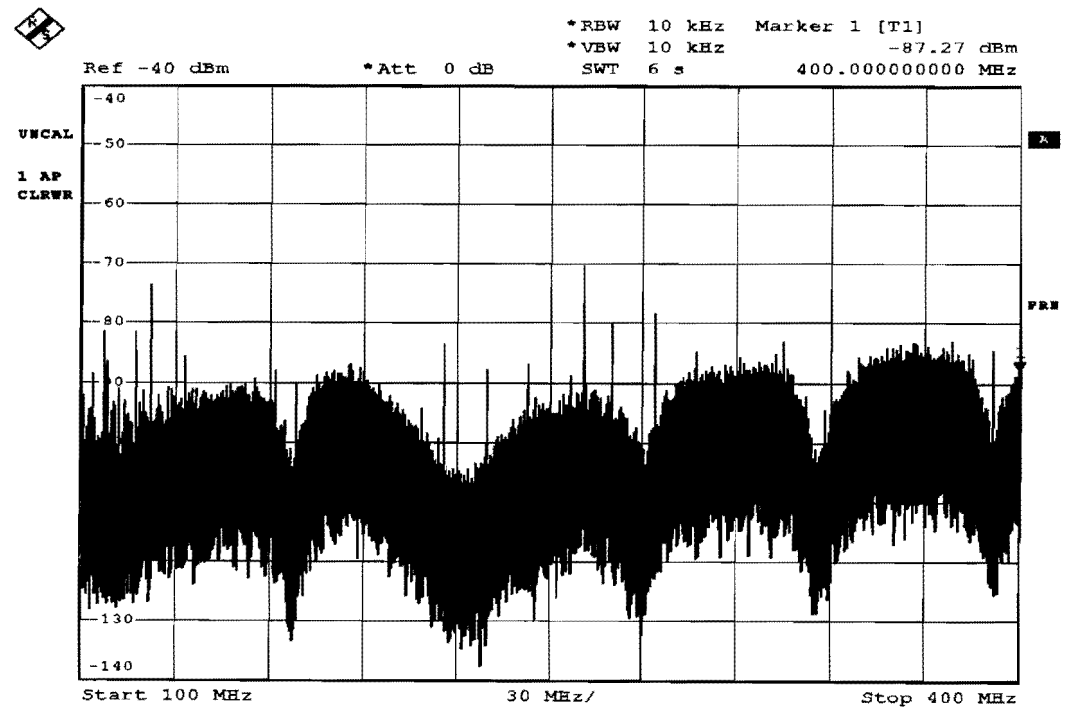

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5. Important Observations

1. LNB Polarization is changed by changing the DC voltage from the Set top box.
2. 14 V is used for Horizontal and 18 V for vertical polarization.
3. To set LO of the LNB, 22 Khz 1 Vppk sine wave is sent from set top box.
4. LNB IF output is broadband, typically 100MHz to 2.5GHz.
5. At LNB output, apart from the genuine satellite signals, the broadband as well as Narrow band noise exists.
6. For Broad band noise, peak power observed is -65dBm/100KHz for Horizontal polarization.
7. Lot of spurious having broadband nature is seen in the GMRT band, which may be because of the inter-modulation products produced in the LNB cable.
8. For Narrow band noise, peak observed is -70dBm.
9. The Narrow band lines are because of the microprocessor and clock circuitry in the set top box, as even if the LNB is disconnected, the Narrow band lines exists.
10. Narrow band lines are more between 100MHz to 400MHz.
11. It is possible that this power can get radiated from the poor cable causing RFI to GMRT.
12. The set top box available in the market, usually consists of a embedded card which includes the majority of the set top box circuitry, SMPS and display card.
13. The set top box has 'loop out' terminal, which duplicates the LNB spectrum, so that one set top box can drive another one.
14. The experiment was conducted on 25 Feb 05, in which the DTH system was mounted on Guest House and kept ON -OFF -ON for 3 minutes each and central square antennas were pointed towards Guest House. We have not found any correlation between DTH ON and OFF and change of Power at GMRT Correlator output.

6. DTH-RFI estimates for GMRT

As seen from the various spectrums, lot of broadband as well as narrow band noise does exist in the LNB cable, which has no use to DTH reception but may cause RFI to GMRT, if the part of the conducted power gets radiated out. Two types of noises are observed, one broadband and another narrow band. One has to treat the two types in different manner. Our approach is to estimate the possible RFI to GMRT from DTH, by computing the minimum separation distance of DTH system from GMRT antenna, so that ITU-R requirements are met.

Analysis for Broadband Noise

1.Let the wire along with the connectors, acts as a radiator with 0dBi gain.
2.Let the radiated power from the cable is 60dB down from the conducted power.
(Assumption is based on the European Emission Standard EN50081-1, which perhaps would be the worst-case)
3.For broadband noise the peak power is -65dBm in 100KHz bandwidth for Horizontal polarization.
4.As per the ITU-R standards for Radio Telescopes, the harmful level of RFI for GMRT in Continuum mode is -255dBW/m^2- Hz.

Calculations: -
Power in the cable, Pc = -65dBm/100KHz
Pc = --95dBW/100KHz
Pc = -145dBW/Hz
So the radiated power is 60 dB down Pc;
Pr = -205dBW/Hz.
Now the Flux at the distance R from the source is given by;

$$F=\frac{P*G}{(4\pi*R^2)}$$

$$R=\sqrt{\frac{P*G}{(4\pi*F)}}$$

$$Now\ for\ GMRT,\ F=-255\ dBW/m^2-Hz$$

$$also\ P=Pr=-205\ dBW/Hz,\ G=0\ dBi=1$$

$$10\log R=\frac{1}{2}*[10\log P+10\log G-10\log(4\pi)-10\log F]$$

putting all values ;

$$10\log R=\frac{1}{2}*[-205+0-10.992-(-255)]$$

$$10\log R=19.504$$

therefore ;

$$R=89.207\ meters$$

Thus if the separation distance of DTH system and GMRT antenna is 89.207 meters, then the broadband noise under worst case would cause RFI which will just touch the GMRT sensitivity. For Broad band noise with power -80dBm/100KHz, the distance at which it will cause RFI is 15.86 meters.
So primary inference can be drawn that broadband noise will have little or negligible effect on GMRT.

Analysis of Narrow band noise

1. Let the wire along with the connectors, acts as a radiator with 0dBi gain.
2. Let the radiated power from the cable is 60dB down from the conducted power.
(Assumption is based on the European Emission Standard EN50081-1which perhaps would be the worst-case)
3. The peak narrow band power observed is -70dBm/Hz.
4. As per the ITU-R standards for Radio Telescopes, the harmful level of RFI for GMRT in spectral line mode is -239dBW/m^2-Hz.

Calculations: -
Power in the cable, Pc = -70dBm/Hz
Pc = -100dBW/Hz
So the radiated power is 60 dB down Pc;
Pr = -160dBW/Hz.
Now the Flux at the distance R from the source is given by;

$$F=\frac{P*G}{(4\pi*R^2)}$$

$$R=\sqrt{\frac{P*G}{(4\pi*F)}}$$

$$Now\ for\ GMRT,\ F=-237\ dBW/m^2-Hz$$

$$also\ P=Pr=-160\ dBW/Hz,\ G=0\ dBi=1$$

$$10\log R=\frac{1}{2}*[10\log P+10\log G-10\log(4\pi)-10\log F]$$

putting all values ;

$$10\log R=\frac{1}{2}*[-160+0-10.992-(-237)]$$

$$10\log R=33.004$$

therefore ;

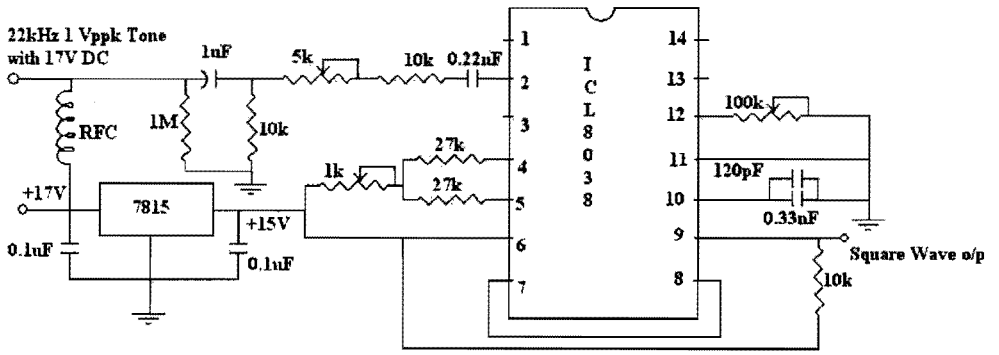
$$R=1.997\ Km$$

Thus if the separation distance of DTH system and GMRT antenna is ~2Kms, then the narrow band noise under worst case would cause RFI which will just touch the GMRT sensitivity.

7. Controlling LNB

To understand the exact spectrum at LNB o/p, it is important to control LNB without the use of set top box. This can be achieved by simulating the signals given by the set top box to LNB by some other circuitry with proper impedance matching. The set top box gives 22kHz tone to LNB to set LO as well as proper DC voltage for power supply and polarization selection.

So to start with, we have used the Intersil 8038 Function Generator IC to generate 22KHz tone and then added proper DC voltage to it. Following Fig. shows the circuit diagram.



Though this circuit gives exactly the same signal and DC voltage as measured in the LNB cable, but when connected to LNB, circuit was unable to control LNB. This may be loading caused by impedance mismatch, and o/p stage of this circuit must be designed for 75ohm. Additional effort to understand and solve the problem could not be put because of time constraints.

Conclusions

Under the (perhaps pessimistic?) assumptions of the radiation behaviour of the coax cable and connectors used in the DTH system as in pages 15 and 16,

1. Broadband noise will have negligible effect on GMRT Observations, as the minimum separation distance is 90 meters with the assumption that there is no DTH system in 100 meter circle from any of the GMRT antennas. Care must be taken for arm antennas.
2. Narrow band noise can cause RFI, in spectral line observations below 400MHz, if located at about 2 km from a GMRT antenna.

9. Further Work

1. It is useful to be able to control LNB without set top box so as to understand the exact spectrum at LNB o/p. Effort is to be put to make the circuit on page 18 (or some other approach) work.

2. Effect of Narrow band noise on GMRT must be studied in detail. Towards this, a DTH Receiver needs to be installed on an evaluation basis at the GMRT Guest House/ Recreation Room and test observations in spectral line mode performed with different "poorly made" coaxial cables to link the LNB and STB. Careful check for lines seen in nearby antennas like C3, C4, C9 etc in 235 and 325 Mhz bands would help in getting a clearer picture regarding the severity of the problem/s in a controlled manner.

3. Finally, to restrict possible RFI, one can design a Hair Pin Filter with provision of passing DC and 22KHz tone which can be added between the LNB and set top box. This will only allow the required satellite signals and attenuate noise in the GMRT band. Depending on the result of (2) above, we may have to plan a strategy of adding such units BEFORE THE STB at installtions in nearby villages.

4. We may find that a simpler solution might be to buy a good quality double-shielded cable, assesmble connectors professionally and supply to the nearby villages, if the tests as in (2) above does show interferance to operation of GMRT.

References: -

1. EN 50221: Common Interface Specifications for conditional access and other Digital video broadcasting decoder applications.
2. IS 15377-2003: Digital Set Top Box for Direct to Home services
3. Effect of corDECT systems on GMRT (Internal Technical Report)

Appendix

TV & Radio Channels from NSS-6 Satellite

TV Channels

Channel No.	Channel Name	Downlink	Bit rate	Polarization	LNB LO	Free/ Paid
1	Kairali TV	12704	27480	Horizontal	10770 Mhz	Free
2	BBC world	12704	27480	Horizontal	10770 Mhz	Free
3	ETC Punjabi	12704	27480	Horizontal	10770 Mhz	Free
4	Smile TV	12704	27480	Horizontal	10770 Mhz	Free
5	Aaj Tak	12704	27480	Horizontal	10770 Mhz	Free
6	Zee music	12704	27480	Horizontal	10770 Mhz	Free
7	Headline Today	12704	27480	Horizontal	10770 Mhz	Free
8	Sun TV	12704	27480	Horizontal	10770 Mhz	Free
9	TV9	12704	27480	Horizontal	10770 Mhz	Free
10	Star Utsav	12704	27480	Horizontal	10770 Mhz	Free
11	ETV Marathi	12704	27480	Horizontal	10770 Mhz	Free
12	Alpha Gujarati	12816	27497	Horizontal	10770 Mhz	Paid
13	N TV	12816	27497	Horizontal	10770 Mhz	Paid
14	Channel 7	12816	27497	Horizontal	10770 Mhz	Paid
15	Play TV	12816	27497	Horizontal	10770 Mhz	Paid
16	SITI Channel	12816	27497	Horizontal	10770 Mhz	Paid
17	CNN Headlines	12705	40679	Vertical	10770 Mhz	Paid
18	CCTV 9	12705	40679	Vertical	10770 Mhz	Paid
19	Jeevan TV	12705	40679	Vertical	10770 Mhz	Paid
20	24x7 NDTV	12705	40679	Vertical	10770 Mhz	Paid
21	TV5 Asia	12705	40679	Vertical	10770 Mhz	Paid
22	Jagaran	12705	40679	Vertical	10770 Mhz	Free
23	Maa TV	12705	40679	Vertical	10770 Mhz	Paid
24	Geo Pak	12705	40679	Vertical	10770 Mhz	Paid
25	ESPN	12705	40679	Vertical	10770 Mhz	Paid
26	Boomrang	12705	40679	Vertical	10770 Mhz	Paid
27	Euro Sport	12705	40679	Vertical	10770 Mhz	Paid
28	Fashion TV	12705	40679	Vertical	10770 Mhz	Paid
29	India TV	12705	40679	Vertical	10770 Mhz	Paid
30	Jaya TV	12705	40679	Vertical	10770 Mhz	Paid
31	Asia Net	12705	40679	Vertical	10770 Mhz	Paid
32	Sahara One	12705	40679	Vertical	10770 Mhz	Paid
33	Sahara Samay	12705	40679	Vertical	10770 Mhz	Paid
34	Dish TV India	12705	40679	Vertical	10770 Mhz	Free
35	VH1	12705	40679	Vertical	10770 Mhz	Paid

38 Reality TV	12765	40682	Vertical	10770 Mhz	Paid
39 Nepal 1	12765	40682	Vertical	10770 Mhz	Paid
40 Cartoon Network	12765	40682	Vertical	10770 Mhz	Paid
41 CNBC	12765	40682	Vertical	10770 Mhz	Paid
42 CNN	12765	40682	Vertical	10770 Mhz	Paid
43 TCM	12765	40682	Vertical	10770 Mhz	Paid
44 Zee Cinema	12765	40682	Vertical	10770 Mhz	Paid
45 Smile TV	12765	40682	Vertical	10770 Mhz	Paid
46 Aaj Tak	12765	40682	Vertical	10770 Mhz	Paid
47 B4U Music	12765	40682	Vertical	10770 Mhz	Paid
48 ABC asia	12765	40682	Vertical	10770 Mhz	Paid
49 Trace TV	12765	40682	Vertical	10770 Mhz	Paid
50 Aastha	12765	40682	Vertical	10770 Mhz	Paid
51 Aakash Bangla	12765	40682	Vertical	10770 Mhz	Paid
52 NDTV India	12765	40682	Vertical	10770 Mhz	Paid
53 Alpha Telugu	12765	40682	Vertical	10770 Mhz	Paid
54 Zee Business	12765	40682	Vertical	10770 Mhz	Paid
55 HBO	12765	40682	Vertical	10770 Mhz	Paid
56 Living Asia	12765	40682	Vertical	10770 Mhz	Paid
57 Zee Sports	12765	40682	Vertical	10770 Mhz	Paid
58 DD One	12816	27497	Vertical	10770 Mhz	Free
59 DD News	12816	27497	Vertical	10770 Mhz	Free
60 DD Sports	12816	27497	Vertical	10770 Mhz	Free
61 DD India	12816	27497	Vertical	10770 Mhz	Free
62 DD Bharati	12816	27497	Vertical	10770 Mhz	Free
63 DD Bangla	12816	27497	Vertical	10770 Mhz	Free
64 DD Chandana	12816	27497	Vertical	10770 Mhz	Free
65 DD Gujarati	12816	27497	Vertical	10770 Mhz	Free
66 DD Kashir	12816	27497	Vertical	10770 Mhz	Free
67 DD Malaylam	12816	27497	Vertical	10770 Mhz	Free
68 DD Lok Sabha	12816	27497	Vertical	10770 Mhz	Free
69 Zee TV	12857	27482	Vertical	10770 Mhz	Paid
70 Zee music	12857	27482	Vertical	10770 Mhz	Paid
71 Zee News	12857	27482	Vertical	10770 Mhz	Paid
72 Alpha Marathi	12857	27482	Vertical	10770 Mhz	Paid
73 Alpha Punjabi	12857	27482	Vertical	10770 Mhz	Paid
74 Alpha Bangali	12857	27482	Vertical	10770 Mhz	Paid
75 Trendz	12857	27482	Vertical	10770 Mhz	Paid

80	DD North East	12899	27483	Vertical	10770 Mhz	Free
81	DD Oriya	12899	27483	Vertical	10770 Mhz	Free
82	DD Podhiya	12899	27483	Vertical	10770 Mhz	Free
83	DD Punjabi	12899	27483	Vertical	10770 Mhz	Free
84	DD Sahyadri	12899	27483	Vertical	10770 Mhz	Free
85	DD Sapthag	12899	27483	Vertical	10770 Mhz	Free
86	Gyandarshan	12899	27483	Vertical	10770 Mhz	Free
87	MH1 Music	12899	27483	Vertical	10770 Mhz	Free
88	Jain TV	12899	27483	Vertical	10770 Mhz	Free
89	Akash Bangla	12899	27483	Vertical	10770 Mhz	Free
90	DD Rajya Sabha	12899	27483	Vertical	10770 Mhz	Free

Radio Channels

Channel No.	Channel Name	Downlink	Bit rate	Polarization	LNB LO	Free/ Paid
1	AIR Kannada	12704	27480	Horizontal	10770 Mhz	Free
2	AIR Bangla	12704	27480	Horizontal	10770 Mhz	Free
3	AIR Hindi	12704	27480	Horizontal	10770 Mhz	Free
4	AIR NE	12704	27480	Horizontal	10770 Mhz	Free
5	RED FM	12765	40682	Vertical	10770 Mhz	Free
6	Punjab Radio	12765	40682	Vertical	10770 Mhz	Free
7	AIR VBS	12816	27497	Vertical	10770 Mhz	Free
8	AIR Telugu	12816	27497	Vertical	10770 Mhz	Free
9	AIR Marathi	12816	27497	Vertical	10770 Mhz	Free
10	AIR Tamil	12816	27497	Vertical	10770 Mhz	Free