Planning Factors (Link Budget) ATSC Mobile DTV
Whitepaper

In the 1990's the FCC defined the planning factors for ATSC DTV service, a link budget containing these planning factor values was then used to calculate the minimum field strength that had to exist at a ATSC receiver antenna to enable reception. The FCC used the F (50, 90) propagation curves to find the distance (miles) to this calculated minimum field strength given the transmit frequency, antenna height, and ERP, this distance from the transmit antenna defined the coverage area of the DTV station. There currently are no published planning factors or a link budget for the new ATSC Mobile DTV service.

Therefore, this white paper develops planning factors for several classes of ATSC Mobile DTV service. A link budget is used to calculate the minimum field strengths, these are then normalized. The FCC F (50, 90) curves are used to find the distance (miles) to this minimum field strength contour (ATSC Mobile DTV). A model UHF DTV station (615 Mhz) with an ERP 1,000 kW, 1,200 HAAT is assumed to carry both normal (A/53) and mobile (A/153) services. A comparison is made of the predicted coverage area for this model station broadcasting both fixed (A/53) and mobile (A/153) services.

Whitepaper

Mike Simon

11.2010-1

ROHDE&SCHWARZ

Introduction

To get a first approximation of the service area an ATSC UHF DTV station can expect for A/153mobile and handheld services, the current ATSC planning factors[1] for (A/53 fixed service) are reviewed. The A/53 planning factors allow the development of a link budget, resulting in the calculated **minimum field strength** needed for service per the FCC rules. For all A/53 ATSC digital television stations, the calculated minimum field strength value is used with the FCC propagation curves derived for 50% of locations and 90% of the time as described in Section 73.699 of FCC rules. The minimum field strength contour is considered the DTV **noise limited coverage area by the FCC.** The FCC curves assume a given ERP and Antenna HAAT. (Height Above Average Terrain) The F (50, 90) distance (miles) to the minimum field strength contour is **independent of the terrain.** The minimum field strength contour (distance) is then used as the area within which to calculate potential DTV service using the Longley-Rice **terrain-dependent** prediction method described in FCC OET Bulletin number 69.

The A/153 planning factors[2] are developed, used to calculate the minimum median field strength for different classes of A/153 reception, Mobile (vehicle), Handheld (pedestrian), both outdoors and inside vehicles and building structures. The distance (miles) to the minimum median field strength contour is found by using the FCC F (50, 90) curves, and using a correction factor (Lh), antenna height of 1.5 meter for A/153. The coverage areas (A/53, A/153) for a UHF DTV station using a 1,000 kW ERP and HAAT 1,200 ft. is presented. A **terrain-dependent** prediction method (not considered) would predict (considering terrain) a smaller service area than the coverage area

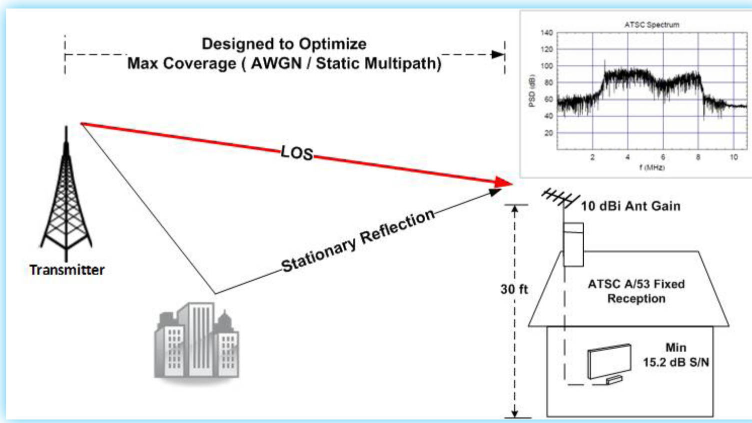

Figure 1 A/53 Fixed Propagation Model

predicted using F (50, 90) curves. Therefore, the A/153 coverage presented is considered generous.

A/53 Planning Factors

Figure 1 shows the A/53 fixed propagation model. The receiver is assumed to have a direct line of sight (LOS) path. The FCC planning factors for UHF assume a receiver Noise Figure (F) of **7 dB.** The thermal noise (Nt) in 6 MHz channel is **-106.2 dBm.** The receiver minimum C/N is **15.2 dB.** The line loss (L) from antenna to receiver is **4 dB.** The dipole conversion factor (FCC Kd) is **130.8 dB**, converts received

[1] See FCC OET-69 Bulletin Table 3 Planning Factors OET --Bulletins On-line

[2] The A/153 planning factors are based on the experience of the wireless industry and use CRC lab data from the LG prototype (FPGA) A/153 receiver

power dBm to field strength in dBu. (dB microvolts/ meter) The antenna gain (G) is **10 dBi.**

Parameter	UHF
Geometric Mean Frequency	615 MHz
Receiver Noise Figure (F)	7 dB
Noise 6 MHz (Nt)	-106.2 dbm
Noise Rx Input	-99.2 dBm
Min required (C/N)	15.2 dB
Min Signal Rx Input	-84.0 dBm
Line Loss (L)	4 dB
Min Signal Power Antenna	-80 dBm
Dipole Conversion Factor(FCC Kd)	130.8 dB
Min Field Strength dBu	50.8 dBu
Gain Antenna (G)	10dBi
Min. Field Strength	**40.8 dBu**

Table 1 FCC A/53 Planning Factors

In table 1 the FCC ATSC A/53 minimum field strength (@ 615 MHz) is 40.8 dBu. To calculate the **minimum field strength (dBu)** equation 1 is used:

$$MinFieldStrength\ (dBu) = F + Nt + c/n + L + Kd - G$$

FCC F(50, 90) Propagation Curves

The FCC uses the minimum field strength (40.8 dBu) and its FCC F (50, 90) propagation curves to find the distance (miles) to the field strength contour, assuming a 30 ft. receive antenna.

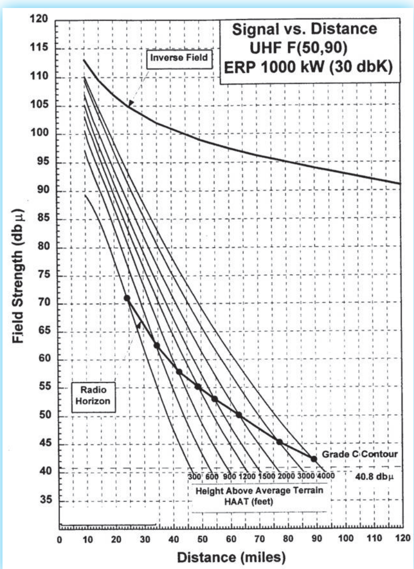

Figure 2 FCC F (50, 90) Propagation Curve

The F (50, 90) propagation curve in figure 2 is for UHF and an ERP 1,000 kW. Along the Y axis is field strength (dBu), along the horizontal axis is distance (miles). Locate 40.8 dBu on the y axis and follow this across plot (dash line) until it intersects with the antenna height. (HAAT) For example a DTV station with an HAAT of 1200 ft. has a distance of **(64.5 miles)** to the 40.8 dBu contour according to the FCC.[3] Note: FCC F(50, 90) curves for other common ERP values can easily be generated. In the next section the planning factors and a link budget for several different A/153 classes of mobile service will be developed. The minimum field strength calculated is then used with the FCC F (50, 90) curve, (1,000 kW ERP, 1,200 ft.) to find distance to the minimum median field strength contours (dBu).

Mobile Enviornment

Figure 3 is the model for the A/153 mobile environment. The mobile receiver antenna is assumed to be only **1.5 meters above ground.** It may be mounted on a moving vehicle or in the case of a handheld receiver may be telescopic or embedded inside the receiver. The mobile and handheld antenna at 1.5 meters has very little clearance to the ground or to close by objects, so these reflecting surfaces in the vicinity of the receive antenna

[3] http://www.tvantenna.tv/papers/PFactorsV.pdf

Paper argues that the FCC planning factors have a shortfall of 8 dB-10 dB and are inadequate for DTV service planning. Note: This paper adopts some of these recommendations for planning of A/153.

will have a **substantial** influence on the characteristics of the propagation path in the mobile environment.

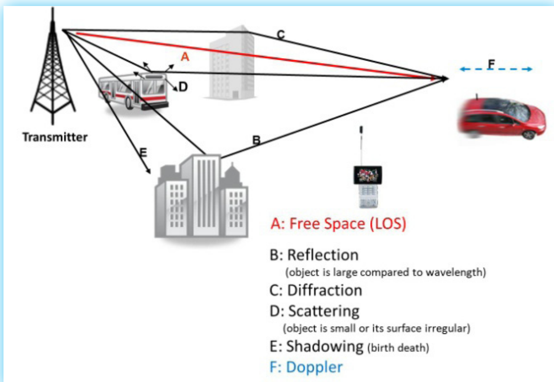

Figure 3 Model of Mobile Environment

A: Free Space Loss - free space loss assumes a transmit antenna and a receive antenna is located in an empty space environment.

B: Reflection - Reflection occurs when a propagating electromagnetic wave impinges on a smooth surface with very large dimensions compared to the RF signal wavelength (λ).

C: Diffraction - diffraction occurs when the propagating path between the transmitter and receiver is obstructed by a dense body with large dimensions compared to wavelength λ. Diffraction is a phenomenon that accounts for the RF energy traveling from transmitter to receiver without a line-of-sight path.

D: Scattering - Scattering occurs when a RF wave impinges on a surface whose dimensions are on the order of λ or less causing the RF reflected energy to be spread out or scattered in all directions.

E: Shadowing - shadowing causes the received signal power to fluctuate due to objects obstructing the propagation path between transmitter and receiver.

F: Doppler - Motion of a receive antenna or reflections from moving objects produces Doppler shifts of incoming RF waves, this affects the amplitude of the resulting signal. These factors are accounted for in the lab fading used to derive the (C/N) values in table 3.

A/153 Planning Factors

Table 2 Class of Mobile/ Handheld Service

Class	Enviornment	Characteristics
Class A	Pedestrian (outdoor)	1.5 M 3 km/h
Class B1	Pedestrian (indoor)	1.5 M 3 km/h
Class B2	Pedestrian (deep indoor)	1.5 M 3 km/h
Class C	Vehicle (roof antenna)	1.5 M 120 km/h
Class D	Vehicle (inside)	1.5 M 120 km/h

Table 2 shows several different classes of services considered in the A/153 link budget.

Table 3 A/153 C/N Lab Tests CRC

Environment (C/N)	¼ SCCC	½ SCCC
AWGN	3.2 dB	7.1 dB
Pedestrian 3 km/h	11.2 dB	15.3 dB
TU6 120 km/h	13 dB	17 dB

Table 3[4] shows the (C/N) for 5% error time, these will be used for planning factors.

[4] CRC Lab Test Report April 2008, LG FPGA prototype receiver. The data reported for Pedestrian and TU6 (Rayleigh) fading are used for A/153 planning factors

Table 4 Receiver Antenna Gain

Antenna	Gain (G)
Handheld (Embedded)	-7 dB
Handheld (Telescopic)	-3 dB
Vehicle (Roof Mounted)	-2 dB

Table 4 shows antenna gains (G). A telescopicantenna is assumed in Class (A, B1, B2, and D).

Table 5 Penetration Loss (Lp) Vehicle and Building

Penetration Loss	Loss (LP)
Class D	7 dB
Class B1	11 dB
Class B2	17 dB

Table 5 shows the penetration loss (Lp) to be used for reception inside a vehicle or indoors in a building in planning factors.

Receiver Noise Figure (F)	6 dB

Table 6 Receiver Noise Figure (F)

Table 6 shows the Receiver Noise Figure that will be used as planning factor.

Thermal Noise 6MHz (Nt)	-106.2 dBm

Table 7 Thermal Noise 6 MHz (Nt)

Table 7 shows the thermal Noise 6 MHz (Nt), that will be used as a planning factor.

Loss Height	dB (Lh)
1.5 M Height	10 dB

Table 8 Antenna Loss Height (Lh) @ 1.5 meter

Table 8 shows the Loss (Lh) for a receiver antenna **height of 1.5 meters** compared to the 30 ft. assumed in A/53 fixed service[5]

Table 9 Correction Factor FCC (Kd) Broadband Signal

(FCC Kd)	Correction Factor	(Kd)
130.8 dB	5 dB	135.8 dB

Table 9 shows correction (5 dB) added to the dipole correction factor (FCC Kd) to correct for a broadband signal. [6] Note: The (FCC Kd) calculation is for a narrowband signal.

Table 10 Quality Coverage Correction Coefficient (Qc)

Quality of Coverage	Correction Coefficient 90% locations (Qc)
Acceptable	1.28

Table 10 shows a correction factor (Qc) for mobile reception at 90 % of the locations.

Table 11 Field Strength Variation (Fv) Correction Factor

Class of Service	Field Strength Variation (Fv)
Class A,C,D	5.5 dB
Class B1	7.4 dB
Class B2	8.1 dB

Table 11 shows value (Fv) field strength variation to be included in planning factors.

Table 12 Other Losses (Lo)

All Other Losses	Loss Other (Lo)
Man-made noise, mismatch, cable, polarization, misc.	3 dB

Table 12 shows all other losses considered (Lo)

A/153 Link Budget

The **minimum median field strength (Emed)** can be calculated using equation 2 below:

$$Emed\ (dBu) = F + Nt + c/n + Kd - G + La + Lp + [(Qc)x(Fv)]$$

[5] (Lh) dB is added to (Emed) dBu to allow use of the FCC F (50, 90) propagation curves (30 ft. antenna height) to the find the distance (miles) to A/153 contour

[6] http://www.tvantenna.tv/apers/PFactorsV.pdf

See figure 13 for explanation of this correction factor

[7] Shows values for ½ SCCC and ¼ SCCC modes, both with P=48 bytes RS-CRC Parity for packet layer FEC

Table 13 (Emed) Minimum Median Field Strength (dBu)

Class of Service	**¼ SCCC**	**½ SCCC**
Pedestrian Outdoor (A)	63 dBu	67 dBu
Pedestrian Indoor (B1)	77 dBu	81 dBu
Pedestrian Deep Indoor (B2)	84 dBu	88 dBu
Vehicle Roof Antenna (C)	62 dBu	67 dBu
Vehicle Inside (D)	70 dBu	75 dBu

Table 13 [7]shows the A/153 minimum median field strength calculated using equation 2 rounded to nearest integer dB value.

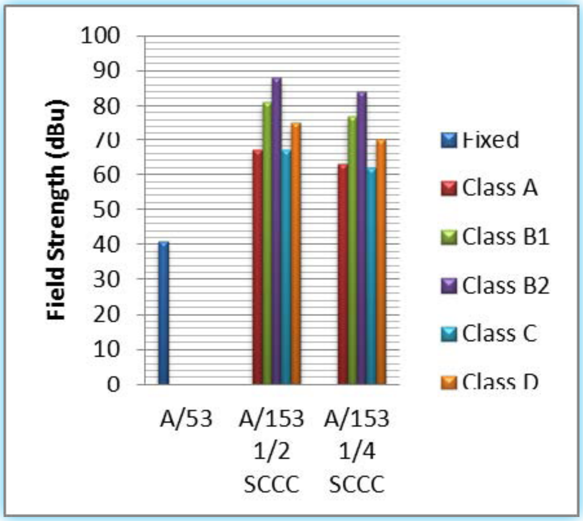

Figure 4 A/53 and A/153 Field Strengths (dBu)

Figure 4 shows a plot of the field strength dBu for both A/53 (fixed) and A/153 (mobile) services. The 40.8 dBu field strength for A/53 (fixed) shown is the value calculated using equation 1. The field strength for each A/153 class of service is shown from left to right (A, B1, B2, C, D) for mode ½ SCCC and mode ¼ SCCC using values from table 13. The strongest field strength shown (88 dBu) is for mode ½ SCCC, Class B2 pedestrian 3 km/h. (deep indoor telescopic antenna) There is a 47 dB delta between the FCC A/53 planning factors (fixed service)and Class B2 A/153 (mobile).

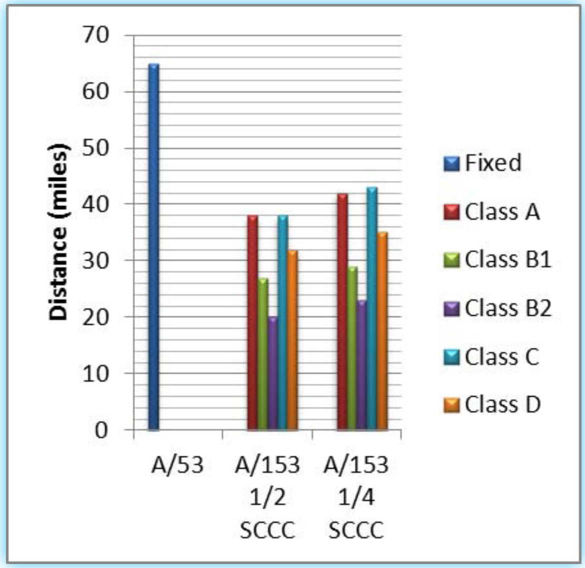

Figure 5 FCC F (50, 90) Distance Miles to Contour

Some of this is due to the planning factors used for A/53, which assumed an ideal (LOS) propagation model and an AWGN limited service. The A/53 planning factors don't match the real world[8] but allowed the FCC to more easily attempt to replicate the NTSC coverage area, their goal.

Next, we will use the FCC F (50, 90) curve figure 2, 1,000 kW ERP, 1,200 feet HAAT, to find the distance (miles) to the field strength values shown in Figure 4. A correction factor (Lh) 10 dB must be added to all the A/153 values shown Figure 4. The FCC F (50, 90) curves use empirical field data collected with an antenna at a height of 30 feet. The height correction factor[9] (Lh) 10 dB assumes 1.5 meter height receiving antenna.

[8] See " Planning Factors for Fixed and Portable DTTV Reception by Oded Bendov, Yiyan Wu, Charles W. Rhodes and John F.X. Browne"

http://www.tvantenna.tv/papers/PFactorsV.pdf

[9] TR102327 version 1.41 April 2009 DVB-H implementation Guidelines; table 11.4 Height Loss shows values for different environments in a range 11-22 dB. The 10 dB (Lh) value chosen in this paper can be considered realistic and maybe conservative.

The **65 mile** distance for (A/53) fixed is shown in Figure 5, along with the distances to the field strength contour for all the A/153 (mobile) Class of service. The shortest distance is seen for the ½ SCCC Class B2 (deep Indoor) **at 20 miles.** The longest distance is for ¼ SCCC Class C (vehicle roof antenna) at **43 miles.** Note: the 43 mile distance can be seen on the FCC F (50, 90) curve figure 2, is located at the Radio Horizon.

Conclusion

This paper developed the planning factors for several classes of ATSC Mobile DTV service. It then normalized the A/153 field strengths calculated, by applying a correction factor (Lh) antenna height. The FCC F (50, 90) curves were then used to find the distance (miles) to this field strength contour. The same UHF DTV station (615 MHz) with an ERP 1,000 kW, 1,200 HAAT was assumed to carry both normal (A/53) and mobile (A/153) services. A comparison was made of the distances (miles) to get an approximation of the coverage area a DTV station could expect for the new mobile (A/153) services, assuming both pedestrian (handheld) and vehicle reception.

To predict the actual A/153 mobile **service area a terrain-dependent propagation model (Software)** would be used to predict service at all locations within the F (50, 90) coverage area. This terrain dependent propagation software would use the A/153 planning factors and a receiver antenna height of 1.5 meters.

[10] There are currently no FCC rules for ATSC Mobile DTV coverage or service prediction.

This propagation software in addition to providing a terrain database may also provide land use databases (building and structures in urban areas) to improve the service location prediction. The resulting terrain dependent mobile service area would normally be smaller than the coverage area predicted using the FCC F (50, 90) propagation curves. Therefore, a good first approximation of the ATSC Mobile DTV service area can be gleaned using the methods[10] described in this paper.

References

ATSC A/53 Standard Part 2: 2007;

http://www.atsc.org/cms/standards/53/a_53-Part-2-2007.pdf

ATSC A/153 Standard Part 2: 2009;

http://www.atsc.org/cms/standards/a153/a_153-Part-2-2009.pdf

FCC OET Bulletin No.69

http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet69/oet69.pdf

Planning Factors for Fixed and Portable DTTVReception; Oded Bendov, Yiyan, Wu, Charles W. Rohdes, John F.X. Browne

http://www.tvantenna.tv/papers/PFactorsV.pdf

DVB-H Implementation Guidelines

http://www.dvbh.org/PDF/a092r3.dTR102377.V1.4.1.DVBH_impl_guide.pdf

Mobile Broadcast Technologies Link BudgetsBMCO forum (White Paper 2/2009)

http://www.bmcoforum.org/index.php?id=256&no_cache=1

Rohde & Schwarz Mobile DTV Solutions

Headend

The R&S®AEM100 multiplexer for ATSC Mobile DTV service combines the functions of IP encapsulation with multiplexing to enable broadcasters to offer new services inside their existing ATSC transport stream. The R&S®AVE264 mobile TV encoder can be teamed with the R&S®AEM100.

Transmission

The R&S®Sx800 is a software configurable television exciter that features adaptive pre-correction for linear and non-linear distortions. The exciter can be adapted to different operating standards and modes, including ATSC Mobile DTV and Single Frequency Networks (SFN). Exciter retrofit packages are available to allow use of the R&S®Sx800 in transmitters produced by other manufacturers.


Transmission

The R&S®Nx8000 family of transmitters is comprised of both liquid (R&S®NV8600) and air-cooled (R&S®NV8300/R&S®NW8200) transmitters for high and medium power applications. All R&S®Nx8000s feature the R&S®Sx800 television exciter for excellent signal performance and flexibility across both VHF and UHF. The R&S®Nx8000 transmitters are very energy efficient with redundant architecture for maximum reliability.

Transmission

The R&S®SCx8000 is the ultimate in efficient design. It consists of the new exciter R&S®SX801 and up to two amplifiers with integrated cooling, combiner and splitter. All major TV standards, including ATSC Mobile DTV are supported with the same hardware. Innovative redundancy concepts make the system highly reliable. Its modular design enables the system to be a stand-alone device, in existing racks and outdoor cabinets.

Test & Measurement

The R&S®ETL TV Analyzer performs 8VSB testing and optional MPEG monitoring in a single unit. It combines TV test receiver and spectrum analyzer functionality while providing high measurement accuracy. Both digital and analog TV standards can be integrated in a single instrument. The R&S®ETL TV Analyzer uses realtime demodulation throughout.

Contacting Rohde & Schwarz

Walt Gumbert
National Account Manager, Transmitter Systems
Rohde & Schwarz, Inc.
8661A Robert Fulton Drive
Columbia, MD 21046
724-693-8171 (Office)
724-312-7700 (Cell)
410-910-7801 (Fax)
e-mail: Walt.Gumbert@RSA.rohde-schwarz.com

Dave Benco
National Key Account Manager
Transmitter Systems
Rohde & Schwarz, Inc.
8661A Robert Fulton Drive
Columbia, MD 21046
724-852-1332 (Office)
724-470-4440 (Cell)
410-910-7801 (Fax)
e-mail: Dave.Benco@rsa.rohde-schwarz.com

Mike Simon
Advanced Technologies Manager
Broadcast Division
Rohde & Schwarz, Inc.
8661-A Robert Fulton Drive
Columbia MD. 21046
e-mail: Mike.Simon@rsa.rohde-schwarz.com

About Rohde & Schwarz
Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

Regional contact
Europe, Africa, Middle East
+49 1805 12 42 42* or +49 89 4129 137 74
customersupport@rohde-schwarz.com

North America
1-888-TEST-RSA (1-888-837-8772)
customer.support@rsa.rohde-schwarz.com

Latin America
+1-410-910-7988
customersupport.la@rohde-schwarz.com

Asia/Pacific
+65 65 13 04 88
customersupport.asia@rohde-schwarz.com

Certified Quality System
ISO 9001
DQS REG. NO 1954 QM

Certified Environmental System
ISO 14001
DQS REG. NO 1954 UM

Rohde & Schwarz GmbH & Co. KG
Mühldorfstraße 15 | D - 81671 München
Phone + 49 89 4129 - 0 | Fax + 49 89 4129 – 13777

www.rohde-schwarz.com